NEW EXPERIMENTS

AND

OBSERVATIONS

ON

ELECTRICITY.

MADE AT

PHILADELPHIA in AMERICA,

BY

BENJAMIN FRANKLIN, Esq;

AND

Communicated in SEVERAL LETTERS

To PETER COLLINSON, Esq; of *London*, F.R.S.

PART I.

The THIRD EDITION.

LONDON:

Printed and Sold by D. HENRY and R. CAVE, at *St John's Gate.* 1760.

[Price 2 *s.* 6 *d.*]

The PREFACE.

IT may be neceſſary to acquaint the Reader, that the following obſervations and experiments were not drawn up with a view to their being made publick, but were communicated at different times, and moſt of them in letters wrote on various topicks, as matters only of private amuſement.

But ſome perſons to whom they were read, and who had themſelves been converſant in electrical diſquiſitions, were of opinion, they contained ſo many curious and intereſting particulars relative to this affair, that it would be doing a kind of injuſtice to the publick, to confine them ſolely to the limits of a private acquaintance.

The Editor was therefore prevailed upon to commit ſuch extracts of letters, and other detach'd pieces as were in his hands to the preſs, without waiting for the ingenious author's permiſſion ſo to do; and this was done with the leſs heſitation, as it was apprehended the author's engagements in other affairs would ſcarce afford him leiſure to give the publick his reflections and experiments on the ſubject, finiſhed with that care and preciſion, of which the treatiſe before us ſhews he is alike ſtudious and capable. He was only apprized of the ſtep that had been thus taken, while the firſt ſheets were in the preſs, and time enough for him to tranſmit ſome farther remarks, together with a few corrections and additions, which are placed at the end, and may be conſulted in the peruſal.

The experiments which our author relates are moſt of them peculiar to himſelf; they are conducted with judgment, and the inferences from them plain and concluſive; though ſometimes propoſed under the terms of ſuppoſitions and conjectures.

And indeed the ſcene he opens, ſtrikes us with a pleaſing aſtoniſhment, while he conducts us by a train of facts and judicious reflections, to a probable cauſe of thoſe phænomena, which are at once the moſt awful, and, hitherto, accounted for with the leaſt veriſimilitude.

He

He exhibits to our conſideration, an inviſible, ſubtile matter, diſſeminated through all nature in various proportions, equally unobſerved, and, whilſt all thoſe bodies to which it peculiarly adheres are alike charged with it, inoffenſive.

He ſhews, however, that if an unequal diſtribution is by any means brought about; if there is a coacervation in one part of ſpace, a leſs proportion, vacuity, or want, in another; by the near approach of a body capable of conducting the coacervated part to the emptier ſpace, it becomes perhaps the moſt formidable and irreſiſtible agent in the univerſe. Animals are in an inſtant ſtruck breathleſs, bodies almoſt impervious by any force yet known, are perforated, and metals fuſed by it, in a moment.

From the ſimilar effects of lightening and electricity our author has been led to make ſome probable conjectures on the cauſe of the former; and, at the ſame time, to propoſe ſome rational experiments in order to ſecure ourſelves, and thoſe things on which its force is often directed, from its pernicious effects; a circumſtance of no ſmall importance to the publick, and therefore worthy of the utmoſt attention.

It has, indeed, been of late the faſhion to aſcribe every grand or unuſual operation of nature, ſuch as lightening and earthquakes, to electricity; not, as one would imagine, from the manner of reaſoning on theſe occaſions, that the authors of theſe ſchemes have, diſcovered any connection betwixt the cauſe and effect, or ſaw in what manner they were related; but, as it would ſeem, merely becauſe they were unacquainted with any other agent, of which it could not poſitively be ſaid the connection was impoſſible.

But of theſe, and many other intereſting circumſtances, the reader will be more ſatisfactorily informed in the following letters, to which he is therefore referred by

The EDITOR.

Fig. I.

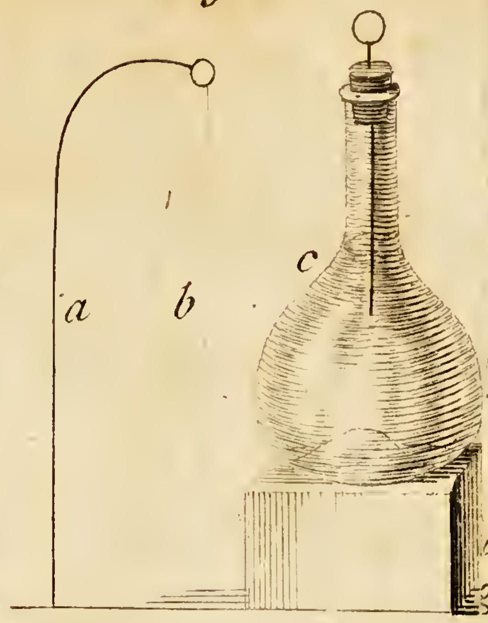
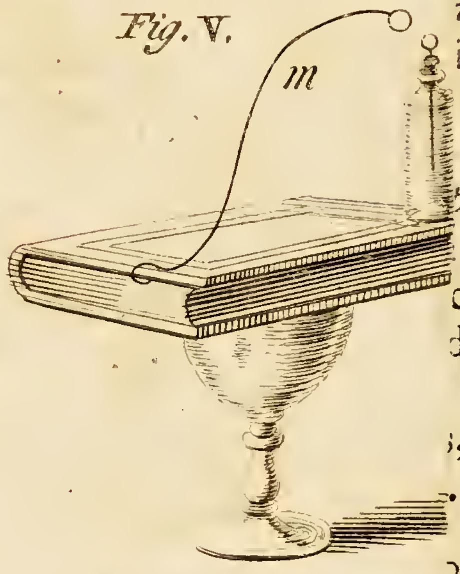
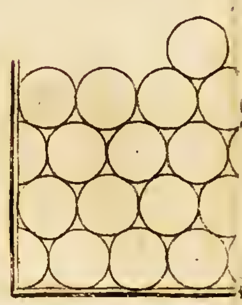
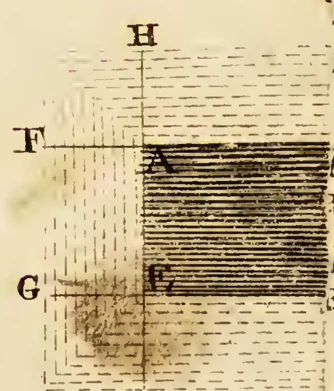


Fig. V.







He e
ter, diſ
equally
culiarly
He ſ
any mea
part of
ther; by
the coac
the moſt
Animals
pervious
fuſed by
From
author
cauſe of
rational
things on
effects;
and ther
It has
grand or
earthqua
manner o
ſchemes h
effect, or
would ſee
other age
nection w
But of
reader w
letters, t

CONTENTS of all the PARTS.

LETTER

CONTENTS.

LET-

LETTER I.

FROM

Mr Benj. Franklin, in *Philadelphia*,

TO

Peter Collinson, Esq; F. R. S. *London*.

S I R, *July* 28, 1747.

THE neceſſary trouble of copying long letters, which perhaps when they come to your hands may contain nothing new, or worth your reading (ſo quick is the progreſs made with you in Electricity) half diſcourages me from writing any more on that ſubject. Yet I cannot forbear adding a few obſervations on M. *Muſchenbroek*'s wonder-bottle.

1. The non-electric contain'd in the bottle differs when electrised from a non-electric electrised out of the bottle, in this: that the electrical fire of the latter is accumulated *on its surface*, and forms an electrical atmosphere round it of considerable extent: but the electrical fire is crowded *into the substance* of the former, the glass confining it.

2. At the same time that the wire and top of the bottle, &c. is electrised *positively* or *plus*, the bottom of the bottle is electrised *negatively* or *minus*, in exact proportion: *i. e.* whatever quantity of electrical fire is thrown in at top, an equal quantity goes out of the bottom. To understand this, suppose the common quantity of electricity in each part of the bottle, before the operation begins, is equal to 20; and at every stroke of the tube, suppose a quantity equal to 1 is thrown in; then, after the first stroke, the quantity contain'd in the wire and upper part of the bottle will be 21, in the bottom 19. After the second, the upper part will have 22, the lower 18, and so on 'till after 20 strokes, the upper part will have a quantity of electrical fire equal to 40, the lower part none: and then the operation ends: for no more can be thrown into the upper part, when no more can be driven out of the lower part. If you attempt to throw more in, it is spued back through the wire, or flies out in loud cracks through the sides of the bottle.

3. The equilibrium cannot be restored in the bottle by *inward* communication or contact of the parts; but it must be done by a communication form'd *without* the bottle,

bottle between the top and bottom, by ſome non-electric, touching both at the ſame time; in which caſe it is reſtored with a violence and quickneſs inexpreſſible; or, touching each alternately, in which caſe the equilibrium is reſtored by degrees.

4. As no more electrical fire can be thrown into the top of the bottle, when all is driven out of the bottom, ſo in a bottle not yet electriſed, none can be thrown into the top, when none *can* get out at the bottom; which happens either when the bottom is too thick, or when the bottle is placed on an electric *per ſe*. Again, when the bottle is electriſed, but little of the electrical fire can be *drawn out* from the top, by touching the wire, unleſs an equal quantity can at the ſame time *get in* at the bottom. Thus, place an electriſed bottle on clean glaſs or dry wax, and you will not, by touching the wire, get out the fire from the top. Place it on a non-electric, and touch the wire, you will get it out in a ſhort time; but ſooneſt when you form a direct communication as above.

So wonderfully are theſe two ſtates of Electricity, the *plus* and *minus* combined and balanced in this miraculous bottle! ſituated and related to each other in a manner that I can by no means comprehend! If it were poſſible that a bottle ſhould in one part contain a quantity of air ſtrongly compreſt, and in another part a perfect vacuum, we know the equilibrium would be inſtantly reſtored *within*. But here we have a bottle containing at the ſame time a *plenum* of electrical fire, and a *vacuum* of the ſame fire; and yet the

the equilibrium cannot be reſtored between them but by a communication *without!* though the *plenum* preſſes violently to expand, and the hungry vacuum ſeems to attract as violently in order to be filled.

5. The ſhock to the nerves (or convulſion rather) is occaſioned by the ſudden paſſing of the fire through the body in its way from the top to the bottom of the bottle. The fire takes the ſhorteſt courſe, as Mr *Watſon* juſtly obſerves: But it does not appear, from experiment, that, in order for a perſon to be ſhocked, a communication with the floor is neceſſary; for he that holds the bottle with one hand, and touches the wire with the other, will be ſhock'd as much, though his ſhoes be dry, or even ſtanding on wax, as otherwiſe. And on the touch of the wire (or of the gun-barrel, which is the ſame thing) the fire does not proceed from the touching finger to the wire, as is ſuppoſed, but from the wire to the finger, and paſſes through the body to the other hand, and ſo into the bottom of the bottle.

EXPERIMENTS *confirming the above.*

EXPERIMENT I.

Place an electriſed phial on wax; a ſmall cork-ball ſuſpended by a dry ſilk-thread held in your hand, and brought near to the wire, will firſt be attracted, and then repelled: when in this ſtate of repellency, ſink your hand, that the ball may be brought towards the bottom of the

the bottle; it will there be inftantly and ftrongly attracted, 'till it has parted with its fire.

If the bottle had an electrical atmofphere, as well as the wire, an electrified cork would be repelled from one as well as from the other.

EXPERIMENT II.

FIG. 1. From a bent wire (*a*) fticking in the table, let a fmall linen thread (*b*) hang down within half an inch of the electrifed phial (*c*). Touch the wire of the phial repeatedly with your finger, and at every touch you will fee the thread inftantly attracted by the bottle. (This is beft done by a vinegar cruet, or fome fuch belly'd bottle). As foon as you draw any fire out from the upper part by touching the wire, the lower part of the bottle draws an equal quantity in by the thread.

EXPERIMENT III.

FIG. 2. Fix a wire in the lead, with which the bottom of the bottle is armed (*d*) fo as that bending upwards, its ring-end may be level with the top or ring-end of the wire in the cork (*e*), and at three or four inches diftance. Then electricife the bottle, and place it on wax. If a cork fufpended by a filk thread (*f*) hang between thefe two wires, it will play inceffantly from one to the other, 'till the bottle is no longer electrifed; that is, it fetches and carries fire from the top to the bottom of the bottle, 'till the equilibrium is reftored.

EX-

EXPERIMENT IV.

FIG. 3. Place an electrifed phial on wax; take a wire *(g)* in form of a *C*, the ends at fuch a diftance when bent, as that the upper may touch the wire of the bottle, when the lower touches the bottom: ftick the outer part on a ftick of fealing-wax (*h*), which will ferve as a handle. Then apply the lower end to the bottom of the bottle, and gradually bring the upper-end near the wire in the cork. The confequence is, fpark follows fpark till the equilibrium is reftored. Touch the top firft, and on approaching the bottom with the other end, you have a conftant ftream of fire, from the wire entering the bottle. Touch the top and bottom together, and the equilibrium will foon be reftored, but filently and imperceptibly; the crooked wire forming the communication.

EXPERIMENT V.

FIG. 4. Let a ring of thin lead or paper furround a bottle (*i*), even at fome diftance from or above the bottom. From that ring let a wire proceed up, till it touch the wire of the cork *(k)*. A bottle fo fixt cannot by any means be electrifed: the equilibrium is never deftroyed: for while the communication between the upper and lower parts of the bottle is continued by the outfide wire, the fire only circulates: what is driven out at bottom, is conftantly fupply'd from the top. Hence a bottle cannot be electrifed that is foul or moift on the outfide.

EX-

EXPERIMENT VI.

Place a man on a cake of wax, and prefent him the wire of the electrified phial to touch, you ftanding on the floor, and holding it in your hand. As often as he touches it, he will be electrified *plus*; and any one ftanding on the floor may draw a fpark from him. The fire in this experiment paffes out of the wire into him; and at the fame time out of your hand into the bottom of the bottle.

EXPERIMENT VII.

Give him the electrical phial to hold; and do you touch the wire; as often as you touch it he will be electrified *minus*, and may draw a fpark from any one ftanding on the floor. The fire now paffes from the wire to you, and from him into the bottom of the bottle.

EXPERIMENT VIII.

Lay two books on two glaffes, back towards back, two or three inches diftant. Set the electrified phial on one, and then touch the wire; that book will be electrified *minus*; the electrical fire being drawn out of it by the bottom of the bottle. Take off the bottle, and holding it in your hand, touch the other with the wire; that book will be electrifed *plus*; the fire paffing into it from the wire, and the bottle at the fame time fupply'd from your hand. A fufpended fmall cork-ball will play between thefe books 'till the equilibrium is reftored.

EX-

EXPERIMENT IX.

When a body is electrifed *plus* it will repel an electrified feather or fmall cork-ball. When *minus* (or when in the common ftate) it will attract them, but ftronger when *minus* than when in the common ftate, the difference being greater.

EXPERIMENT X.

Tho', as in EXPER. VI. a man ftanding on wax may be electrifed a number of times, by repeatedly touching the wire of an electrifed bottle (held in the hand of one ftanding on the floor) he receiving the fire from the wire each time: yet holding it in his own hand, and touching the wire, tho' he draws a ftrong fpark, and is violently fhock'd, no Electricity remains in him; the fire only paffing thro' him from the upper to the lower part of the bottle. Obferve, before the fhock, to let fome one on the floor touch him to reftore the equilibrium in his body; for in taking hold of the bottom of the bottle, he fometimes becomes a little electrifed *minus*, which will continue after the fhock; as would alfo any *plus* Electricity, which he might have given him before the fhock. For, reftoring the equilibrium in the bottle does not at all affect the Electricity in the man thro' whom the fire paffes; that Electricity is neither increafed nor diminifhed.

EXPERIMENT XI.

The paffing of the electrical fire from the upper to the lower part of the bottle, to reftore the equilibrium, is render'd ftrongly vifible by the following pretty experiment.

ment. Take a book whofe cover is filletted with gold; bend a wire of eight or ten inches long in the form of (*m*) Fig. 5. flip it on the end of the cover of the book over the old line, fo as that the fhoulder of it may prefs upon one end of the gold line, the ring up, but leaning towards the other end of the book. Lay the book on a glafs or wax; and on the other end of the gold lines, fet the bottle electrifed; then bend the fpringing wire, by preffing it with a ftick of wax till its ring approaches the ring of the bottle wire; inftantly there is a ftrong fpark and ftroke, and the whole line of gold, which completes the communication between the top and bottom of the bottle, will appear a vivid flame, like the fharpeft lightning. The clofer the contact between the fhoulder of the wire, and the gold at one end of the line, and between the bottom of the bottle and the gold at the other end, the better the experiment fucceeds. The room fhould be darkened. If you would have the whole filletting round the cover appear in fire at once, let the bottle and wire touch the gold in the diagonally oppofite corners.

I am, &c.

B. FRANKLIN.

LETTER II.

FROM

Mr BENJ. FRANKLIN, in *Philadelphia*,

TO

PETER COLLINSON, Efq; F. R. S. *London*.

SIR, *Sept.* 1, 1747.

IN my laft I informed you that, in purfuing our electrical enquiries, we had obferved fome particular Phænomena, which we looked upon to be new, and of which I promifed to give you fome account, tho' I apprehended they might poffibly not be new to you, as fo many hands are daily employ'd in electrical experiments on your fide the water, fome or other of which would probably hit on the fame obfervations.

The firft is the wonderful effect of pointed bodies, both in *drawing off* and *throwing off* the electrical fire. For example:

Place an iron fhot of three or four inches diameter on the mouth of a clean dry glafs bottle. By a fine filken thread from the cieling, right over the mouth of the bottle, fufpend a fmall cork-ball, about the bignefs of a marble; the thread

thread of ſuch a length, as that the cork-ball may reſt againſt the ſide of the ſhot. Electrify the ſhot, and the ball will be repelled to the diſtance of four or five inches, more or leſs, according to the quantity of Electricity.——When in this ſtate, if you preſent to the ſhot the point of a long ſlender ſharp bodkin, at ſix or eight inches diſtance, the repellency is inſtantly deſtroy'd, and the cork flies to the ſhot. A blunt body muſt be brought within an inch, and draw a ſpark, to produce the ſame effect. To prove that the electrical fire is *drawn off* by the point, if you take the blade of the bodkin out of the wooden handle, and fix it in a ſtick of ſealing wax, and then preſent it at the diſtance aforeſaid, or if you bring it very near, no ſuch effect follows; but ſliding one finger along the wax till you touch the blade, and the ball flies to the ſhot immediately.—If you preſent the point in the dark, you will ſee, ſometimes at a foot diſtance, and more, a light gather upon it like that of a fire-fly or glow-worm; the leſs ſharp the point, the nearer you muſt bring it to obſerve the light; and at whatever diſtance you ſee the light, you may draw off the electrical fire, and deſtroy the repellency.—If a cork-ball ſo ſuſpended be repelled by the tube, and a point be preſented quick to it, tho' at a conſiderable diſtance, 'tis ſurprizing to ſee how ſuddenly it flies back to the tube. Points of wood will do as well as thoſe of iron, provided the wood is not dry; for perfectly dry wood will no more conduct Electricity than ſealing wax.

To ſhew that points will *throw off* as well as *draw off* the electrical fire; lay a long ſharp needle upon the ſhot, and you cannot electriſe the ſhot, ſo as to make it repel the cork-ball.—Or fix a needle to the end of a ſuſpended gun-barrel, or iron rod, ſo as to point beyond it like a little bayonet; and while it remains there, the gun-barrel, or rod, cannot by applying the tube to the other end be electriſed ſo as to give a ſpark, the fire continually running out ſilently at the point. In the dark you may ſee it make the ſame appearance as it does in the caſe beforementioned.

The repellency between the cork-ball and the ſhot is likewiſe deſtroy'd. 1. By ſifting fine ſand on it; this does it gradually. 2. By breathing on it. 3. By making a ſmoke about it from burning wood. * 4. By candle light, even tho' the candle is at a foot diſtance: theſe do it ſuddenly.—The light of a bright coal from a wood fire; and the light of red-hot iron do it likewiſe; but not at ſo great a diſtance. Smoke from dry roſin dropt on hot iron, does not deſtroy the repellency; but is attracted by both ſhot and cork-ball, forming proportionable atmoſpheres round them, making them look beautifully, ſomewhat like ſome of the figures in *Burnet*'s or *Whiſton*'s theory of the earth.

* We ſuppoſe every particle of ſand, moiſture, or ſmoke, being firſt attracted and then repelled, carries off with it a portion of the electrical fire; but that the ſame ſtill ſubſiſts in thoſe particles, till they communicate it to ſomething elſe; and that it is never really deſtroyed.—So when water is thrown on common fire, we do not imagine the element is thereby deſtroyed or annihilated, but only diſperſed, each particle of water carrying off in vapour its portion of the fire, which it had attracted and attached to itſelf.

N. B. This

N. B. This experiment ſhould be made in a cloſet here the air is very ſtill.

The light of the ſun thrown ſtrongly on both cork and ſhot by a looking-glaſs for a long time together, does not impair the repellency in the leaſt. This difference between fire-light and ſun-light, is another thing that ſeems new and extraordinary to us.

We had for ſome time been of opinion, that the electrical fire was not created by friction, but collected, being really an element diffus'd among, and attracted by other matter, particularly by water and metals. We had even diſcovered and demonſtrated its afflux to the electrical ſphere, as well as its efflux, by means of little light windmill wheels made of ſtiff paper vanes, fixed obliquely and turning freely on fine wire axes. Alſo by little wheels of the ſame matter, but formed like water wheels. Of the diſpoſition and application of which wheels, and the various phænomena reſulting, I could, if I had time, fill you a ſheet. The impoſſibility of electriſing one's ſelf (tho' ſtanding on wax) by rubbing the tube and drawing the fire from it; and the manner of doing it by paſſing the tube near a perſon or thing ſtanding on the floor, &c. had alſo occurred to us ſome months before Mr *Watſon*'s ingenious *Sequel* came to hand, and theſe were ſome of the new things I intended to have communicated to you.—But now I need only mention ſome particulars not hinted in that piece, with our reaſonings thereupon; though perhaps the latter might well enough be ſpared.

1. A per-

1. A perſon ſtanding on wax, and rubbing the tube, and another perſon on wax drawing the fire; they will both of them, (provided they do not ſtand ſo as to touch one another) appear to be electriſed, to a perſon ſtanding on the floor; that is, he will perceive a ſpark on approaching each of them with his knuckle.

2. But if the perſons on wax touch one another during the exciting of the tube, neither of them will appear to be electriſed.

3. If they touch one another after exciting the tube, and drawing the fire as aforeſaid, there will be a ſtronger ſpark between them, than was between either of them and the perſon on the floor.

4. After ſuch ſtrong ſpark, neither of them diſcover any electricity.

Theſe appearances we attempt to account for thus. We ſuppoſe, as aforeſaid, that electrical fire is a common element, of which every one of the three perſons abovementioned has his equal ſhare, before any operation is begun with the tube. *A*, who ſtands on wax and rubs the tube, collects the electrical fire from himſelf into the glaſs; and his communication with the common ſtock being cut off by the wax, his body is not again immediately ſupply'd. *B*, (who ſtands on wax likewiſe) paſſing his knuckle along near the tube, receives the fire which was collected by the glaſs from *A*; and his communication with the common ſtock being likewiſe cut off, he retains the additional quantity received.—To *C*, ſtanding on the floor, both appear

to

to be electrifed: for he having only the middle quantity of electrical fire, receives a fpark upon approaching *B*, who has an over quantity; but gives one to *A*, who has an under quantity. If *A* and *B* approach to touch each other, the fpark is ftronger, becaufe the difference between them is greater; after fuch touch there is no fpark between either of them and *C*, becaufe the electrical fire in all is reduced to the original equality. If they touch while electrifing, the equality is never deftroy'd, the fire only circulating. Hence have arifen fome new terms among us: we fay, *B*, (and bodies like circumftanced) is electrifed *pofitively*; *A*, *negatively*. Or rather, *B* is electrifed *plus*; *A*, *minus*. And we daily in our experiments electrife bodies *plus* or *minus* as we think proper.—To electrife *plus* or *minus*, no more needs to be known than this, that the parts of the tube or fphere that are rubbed, do, in the inftant of the friction attract the electrical fire, and therefore take it from the thing rubbing: the fame parts immediately, as the friction upon them ceafes, are difpofed to give the fire they have received, to any body that has lefs. Thus you may circulate it, as Mr *Watfon* has fhewn; you may alfo accumulate or fubftract it upon or from any body, as you connect that body with the rubber or with the receiver, the communication with the common ftock being cut off. We think that ingenious gentleman was deceived, when he imagined (in his *Sequel*) that the electrical fire came down the wire from the cieling to the gun-barrel, thence to the fphere, and fo electrifed the machine

and

and the man turning the wheel, *&c.* We ſuppoſe it was *driven off*, and not brought on through that wire; and that the machine and man, *&c.* were electriſed *minus*; *i. e.* had leſs electrical fire in them than things in common.

As the veſſel is juſt upon ſailing, I cannot give you ſo large an account of *American* Electricity as I intended: I ſhall only mention a few particulars more,——We find granulated lead better to fill the phial with, than water, being eaſily warmed, and keeping warm and dry in damp air.—We fire ſpirits with the wire of the phial.——We light candles, juſt blown out, by drawing a ſpark among the ſmoke between the wire and ſnuffers.—We repreſent lightning, by paſſing the wire in the dark over a china plate that has gilt flowers, or applying it to gilt frames of looking-glaſſes, &c.—We electriſe a perſon twenty or more times running, with a touch of the finger on the wire, thus: He ſtands on wax. Give him the electriſed bottle in his hand. Touch the wire with your finger, and then touch his hand or face; there are ſparks every time.—We increaſe the force of the electrical kiſs vaſtly, thus: Let *A* and *B* ſtand on wax; give one of them the electriſed phial in hand; let the other take hold of the wire; there will be a ſmall ſpark; but when their lips approach, they will be ſtruck and ſhock'd. The ſame if another gentleman and lady, *C* and *D*, ſtanding alſo on wax, and joining hands with *A* and *B*, ſalute, or ſhake hands.—We ſuſpend by fine ſilk thread a counterfeit ſpider, made of a ſmall piece of burnt cork, with legs of linnen thread,

thread, and a grain or two of lead ſtuck in him to give him more weight. Upon the table, over which he hangs, we ſtick a wire upright as high as the phial and wire, two or three inches from the ſpider; then we animate him by ſetting the electrified phial at the ſame diſtance on the other ſide of him; he will immediately fly to the wire of the phial, bend his legs in touching it, then ſpring off; and fly to the wire in the table; thence again to the wire of the phial, playing with his legs againſt both in a very entertaining manner, appearing perfectly alive to perſons unacquainted. He will continue this motion an hour or more in dry weather.—We electrify, upon wax in the dark, a book that has a double line of gold round upon the covers, and then apply a knuckle to the gilding; the fire appears every where upon the gold like a flaſh of lightning: not upon the leather, nor, if you touch the leather inſtead of the gold. We rub our tubes with buckſkin, and obſerve always to keep the ſame ſide to the tube, and never to ſully the tube by handling; thus they work readily and eaſily, without the leaſt fatigue; eſpecially if kept in tight paſtboard caſes, lined with flannel, and fitting cloſe to the tube.*—This I mention becauſe the *European* papers, on Electricity, frequently ſpeak of rubbing the tube, as a fatiguing exerciſe. Our ſpheres are fixed on iron axes, which paſs through them. At one end of the

* Our tubes are made here of green glaſs, 27 or 30 inches long, as big as can be graſped. Electricity is ſo much in vogue, that above one hundred of them have been ſold within theſe four months paſt.

axis there is a ſmall handle, with which you turn the ſphere like a common grindſtone. This we find very commodious, as the machine takes up but little room, is portable, and may be encloſed in a tight box, when not in uſe. 'Tis true, the ſphere does not turn ſo ſwift, as when the great wheel is uſed: but ſwiftneſs we think of little importance, ſince a few turns will charge the phial, *&c.* ſufficiently.

I am, &c.

B. FRANKLIN.

LET-

LETTER III.

FROM

Mr BENJ. FRANKLIN, in *Philadelphia*,

TO

PETER COLLINSON, Esq; F. R. S. *London*.

Farther EXPERIMENTS *and* OBSERVATIONS *in* ELECTRICITY.

SIR, 1748.

§ 1. THERE will be the same explosion and shock if the electrified phial is held in one hand by the hook, and the coating touch'd with the other, as when held by the coating, and touch'd at the hook.

2. To take the charg'd phial safely by the hook, and not at the same time diminish its force, it must first be set down on an electric *per se*.

3. The phial will be electrified as strongly, if held by the hook, and the coating apply'd to the globe or tube; as when held by the coating, and the hook apply'd.

 4. But

4. But the *direction* of the electrical fire being different in the charging, will alſo be different in the exploſion. The bottle charged thro' the hook, will be diſcharged thro' the hook; the bottle charged thro' the coating, will be diſcharged thro' the coating, and not otherways: for the fire muſt come out the ſame way it went in.

5. To prove this; take two bottles that were equally charged thro' the hooks, one in each hand; bring their hooks near each other, and no ſpark or ſhock will follow; becauſe each hook is diſpoſed to give fire, and neither to receive it. Set one of the bottles down on glaſs, take it up by the hook, and apply its coating to the hook of the other; then there will be an exploſion and ſhock, and both bottles will be diſcharged.

6. Vary the experiment, by charging two phials equally, one thro' the hook, the other thro' the coating: hold that by the coating which was charged thro' the hook; and that by the hook which was charged thro' the coating: apply the hook of the firſt to the coating of the other, and there will be no ſhock or ſpark. Set that down on glaſs which you held by the hook, take it up by the coating, and bring the two hooks together: a ſpark and ſhock will follow, and both phials be diſcharged.

In this experiment the bottles are totally diſcharged, or the equilibrium within them reſtored. The *abounding* of fire in one of the hooks (or rather in the internal ſurface of one bottle) being exactly equal to the *wanting* of the other: and therefore, as each bottle has in itſelf the *abounding* as

well

well as the *wanting*, the wanting and abounding muſt be equal in each bottle. See §. 8, 9, 10, 11. But if a man holds in his hands two bottles, one fully electrify'd, the other not at all, and brings their hooks together, he has but half a ſhock, and the bottles will both remain half electrified, the one being half diſcharged, and the other half charged.

7. Place two phials equally charged on a table at five or ſix inches diſtance. Let a cork-ball, ſuſpended by a ſilk thread, hang between them. If the phials were both charged through their hooks, the cork, when it has been attracted and repell'd by the one, will not be attracted, but equally repelled by the other. But if the phials were charged, the one thro' the hook, and the other * thro' the coating, the ball, when it is repelled from one hook, will be as ſtrongly attracted by the other, and play vigorouſly between them, 'till both phials are nearly diſcharged.

8. When we uſe the terms of *charging* and *diſcharging* the phial, 'tis in compliance with cuſtom, and for want of others more ſuitable. Since we are of opinion, that there is really no more electrical fire in the phial after what is called its *charging*, than before, nor leſs after its *diſcharging*; excepting only the ſmall ſpark that might be given to, and taken from, the non-electric matter, if ſeparated from

* To charge a bottle commodiouſly through the coating, place it on a glaſs ſtand; form a communication from the prime conductor to the coating, and another from the hook to the wall or floor. When it is charged, remove the latter communication before you take hold of the bottle, otherwiſe great part of the fire will eſcape by it.

the bottle, which ſpark may not be equal to a five hundredth part of what is called the exploſion.

For if, on the exploſion, the electrical fire came out of the bottle by one part, and did not enter in again by another; then, if a man ſtanding on wax, and holding the bottle in one hand, takes the ſpark by touching the wire hook with the other, the bottle being thereby *diſcharged*, the man would be *charged*; or whatever fire was loſt by one, would be found in the other, ſince there was no way for its eſcape: But the contrary is true.

9. Beſides, the phial will not ſuffer what is called a *charging*, unleſs as much fire can go out of it one way, as is thrown in by another. A phial cannot be charged ſtanding on wax or glaſs, or hanging on the prime conductor, unleſs a communication be formed between its coating and the floor.

10. But ſuſpend two or more phials on the prime conductor, one hanging to the tail of the other; and a wire from the laſt to the floor, an equal number of turns of the wheel ſhall charge them all equally, and every one as much as one alone would have been. What is driven out at the tail of the firſt, ſerving to charge the ſecond; what is driven out of the ſecond charging the third; and ſo on. By this means a great number of bottles might be charged with the ſame labour, and equally high, with one alone, were it not that every bottle receives new fire, and loſes its old with ſome reluctance, or rather gives ſome ſmall reſiſtance to the charging, which in a number of bottles becomes

comes more equal to the charging power, and ſo repels the fire back again on the globe, ſooner than a ſingle bottle would do.

11. When a bottle is charged in the common way, its *inſide* and *outſide* ſurfaces ſtand ready, the one to give fire by the hook, the other to receive it by the coating; the one is full, and ready to throw out, the other empty and extremely hungry; yet as the firſt will not *give out*, unleſs the other can at the ſame inſtant *receive in*; ſo neither will the latter receive in, unleſs the firſt can at the ſame inſtant give out. When both can be done at once, 'tis done with inconceivable quickneſs and violence.

12. So a ſtrait ſpring (tho' the compariſon does not agree in every particular) when forcibly bent, muſt, to reſtore itſelf, contract that ſide which in the bending was extended, and extend that which was contracted; if either of theſe two operations be hindered, the other cannot be done. But the ſpring is not ſaid to be *charg'd* with elaſticity when bent, and diſcharg'd when unbent; its quantity of elaſticity is always the ſame.

13. Glaſs, in like manner, has, within its ſubſtance, always the ſame quantity of electrical fire, and that a very great quantity in proportion to the maſs of glaſs, as ſhall be ſhewn hereafter.

14. This quantity, proportioned to the glaſs, it ſtrongly and obſtinately retains, and will have neither more nor leſs, though it will ſuffer a change to be made in its parts and ſituation; *i. e.* we may take away part of it from one

of

of the fides, provided we throw an equal quantity into the other.

15. Yet when the fituation of the electrical fire is thus altered in the glafs; when fome has been taken from one fide, and fome added to the other, it will not be at reft or in its natural ftate, till 'tis reftored to its original equality.— And this reftitution cannot be made through the fubftance of the glafs, but muft be done by a non-electric communication formed without, from furface to furface.

16. Thus, the whole force of the bottle, and power of giving a fhock, is in the GLASS ITSELF; the non-electrics in contract with the two furfaces, ferving only to *give* and *receive* to and from the feveral parts of the glafs; that is, to give on one fide, and take away from the other.

17. This was difcovered here in the following manner: Purpofing to analyfe the electrified bottle, in order to find wherein its ftrength lay, we placed it on glafs, and drew out the cork and wire which for that purpofe had been loofely put in. Then taking the bottle in one hand, and bringing a finger of the other near its mouth, a ftrong fpark came from the water, and the fhock was as violent as if the wire had remained in it, which fhewed that the force did not lie in the wire. Then to find if it refided in the water, being crouded into and condenfed in it, as confin'd by the glafs, which had been our former opinion, we electrify'd the bottle again, and placing it on glafs, drew out the wire and cork as before; then taking up the bottle, we decanted all its water into an empty bottle, which likewife ftood on

glafs;

glaſs; and taking up that other bottle, we expected if the force reſided in the water, to find a ſhock from it; but there was none. We judged then, that it muſt either be loſt in decanting, or remain in the firſt bottle. The latter we found to be true: for that bottle on trial gave the ſhock, though filled up as it ſtood with freſh unelectrified water from a tea-pot.—To find then, whether glaſs had this property merely as glaſs, or whether the form contributed any thing to it; we took a pane of ſaſh-glaſs, and laying it on the hand, placed a plate of lead on its upper ſurface; then electrify'd that plate, and bringing a finger to it, there was a ſpark and ſhock. We then took two plates of lead of equal dimenſions, but leſs than the glaſs by two inches every way, and electrified the glaſs between them, by electrifying the uppermoſt lead; then ſeparated the glaſs from the lead, in doing which, what little fire might be in the lead was taken out, and the glaſs being touched in the electrified parts with a finger, afforded only very ſmall pricking ſparks, but a great number of them might be taken from different places. Then dexterouſly placing it again between the leaden plates, and compleating a circle between the two ſurfaces, a violent ſhock enſued.——Which demonſtrated the power to reſide in glaſs as glaſs, and that the non-electrics in contact ſerved only, like the armature of a loadſtone, to unite the force of the ſeveral parts, and bring them at once to any point deſired: it being a property of a non-electric, that the

whole body inftantly receives or gives what electrical fire is given to or taken from any one of its parts.

18. Upon this, we made what we call'd an *electrical-battery*, confifting of eleven panes of large fafh-glafs, arm'd with thin leaden plates pafted on each fide, placed vertically, and fupported at two inches diftance on filk cords, with thick hooks of leaden wire, one from each fide, ftanding upright, diftant from each other, and convenient communications of wire and chain, from the giving fide of one pane, to the receiving fide of the other; that fo the whole might be charged together, and with the fame labour as one fingle pane; and another contrivance to bring the giving fides, after charging, in contract with one long wire, and the receivers with another, which two long wires would give the force of all the plates of glafs at once through the body of any animal forming the circle with them. The plates may alfo be difcharged feparately, or any number together that is required. But this machine is not much ufed, as not perfectly anfwering our intention with regard to the eafe of charging, for the reafon given §. 10. We made alfo of large glafs panes, magical pictures, and felf-moving animated wheels, prefently to be defcribed.

19. I perceive by the ingenious Mr *Watfon*'s laft book, lately received, that Dr *Bevis* had ufed, before we had, panes of glafs to give a fhock; though, till that book came to hand, I thought to have communicated it to you as a novelty. The excufe for mentioning it here is, that we

tried

tried the experiment differently, drew different consequences from it, (for Mr *Watſon* ſtill ſeems to think the fire *accumulated on the non-electric* that is in contact with the glaſs, page 72) and, as far as we hitherto know, have carried it farther.

20. The magical picture is made thus. Having a large metzotinto with a frame and glaſs, ſuppoſe of the KING, (God preſerve him) take out the print, and cut a pannel out of it, near two inches diſtant from the frame all round. If the cut is through the picture 'tis not the worſe. With thin paſte, or gum-water, fix the border that is cut off on the inſide of the glaſs, preſſing it ſmooth and cloſe; then fill up the vacancy by gilding the glaſs well with leaf gold or braſs. Gild likewiſe the inner edge of the back of the frame all round except the top part, and form a communication between that gilding and the gilding behind the glaſs: then put in the board, and that ſide is finiſhed. Turn up the glaſs, and gild the fore ſide exactly over the back gilding, and when it is dry, cover it by paſting on the pannel of the picture that hath been cut out, obſerving to bring the correſpondent parts of the border and picture together, by which the picture will appear of a piece as at firſt, only part is behind the glaſs, and part before.—Hold the picture horizontally by the top, and place a little moveable gilt crown on the king's head. If now the picture be moderately electrified, and another perſon take hold of the frame with one hand, ſo that his fingers touch its inſide gilding, and with the other hand endeavour to take

off the crown, he will receive a terrible blow, and fail in the attempt. If the picture were highly charged, the consequence might perhaps be as fatal as that of high-treason; for when the spark is taken through a quire of paper laid on the picture, by means of a wire communication, it makes a fair hole thro' every sheet, that is, thro' 48 leaves, (though a quire of paper is thought good armour against the push of a sword, or even against a pistol bullet) and the crack is exceeding loud. The operator, who holds the picture by the upper end, where the inside of the frame is not gilt, to prevent its falling, feels nothing of the shock, and may touch the face of the picture without danger, which he pretends is a test of his loyalty.——If a ring of persons take the shock among them, the experiment is called, *The Conspirators*.

21. On the principle, in §. 7, that hooks of bottles, differently charged, will attract and repel differently, is made an electrical wheel, that turns with considerable strength. A small upright shaft of wood passes at right angles through a thin round board, of about twelve inches diameter, and turns on a sharp point of iron fixed in the lower end, while a strong wire in the upper end passing thro' a small hole in a thin brass plate, keeps the shaft truly vertical. About thirty *radii* of equal length, made of sash-glass cut in narrow strips, issue horizontally from the circumference of the board, the ends most distant from the center being about four inches apart. On the end of every one, a brass thimble is fixed. If now the wire of a bottle electrified in the

common

common way, be brought near the circumference of this wheel, it will attract the neareſt thimble, and ſo put the wheel in motion; that thimble, in paſſing by, receives a ſpark, and thereby being electrified is repelled, and ſo driven forwards; while a ſecond being attracted, approaches the wire, receives a ſpark, and is driven after the firſt, and ſo on till the wheel has gone once round, when the thimbles before electrified approaching the wire, inſtead of being attracted as they were at firſt, are repelled, and the motion preſently ceaſes.—But if another bottle which had been charged through the coating be placed near the ſame wheel, its wire will attract the thimble repelled by the firſt, and thereby double the force that carries the wheel round; and not only taking out the fire that had been communicated to the thimbles by the firſt bottle, but even robbing them of their natural quantity, inſtead of being repelled when they come again towards the firſt bottle, they are more ſtrongly attracted, ſo that the wheel mends its pace, till it goes with great rapidity twelve or fifteen rounds in a minute, and with ſuch ſtrength, as that the weight of one hundred *Spaniſh* dollars with which we once loaded it, did not ſeem in the leaſt to retard its motion.—This is called an electrical jack; and if a large fowl were ſpitted on the upright ſhaft, it would be carried round before a fire with a motion fit for roaſting.

22. But this wheel, like thoſe driven by wind, water, or weights, moves by a foreign force, to wit, that of the bottles. The ſelf-moving wheel, though conſtructed on the

ſame

ſame principles, appears more ſurpriſing. 'Tis made of a thin round plate of window-glaſs, ſeventeen inches diameter, well gilt on both ſides, all but two inches next the edge. Two ſmall hemiſpheres of wood are then fixed with cement to the middle of the upper and under ſides, centrally oppoſite, and in each of them a thick ſtrong wire eight or ten inches long, which together make the axis of the wheel. It turns horizontally on a point at the lower end of its axis, which reſts on a bit of braſs cemented within a glaſs ſalt-cellar. The upper end of its axis paſſes thro' a hole in a thin braſs plate cemented to a long ſtrong piece of glaſs, which keeps it ſix or eight inches diſtant from any non-electric, and has a ſmall ball of wax or metal on its top to keep in the fire. In a circle on the table which ſupports the wheel, are fixed twelve ſmall pillars of glaſs, at about four inches diſtance, with a thimble on the top of each. On the edge of the wheel is a ſmall leaden bullet, communicating by a wire with the gilding of the *upper* ſurface of the wheel; and about ſix inches from it is another bullet communicating in like manner with the *under* ſurface. When the wheel is to be charged by the upper ſurface, a communication muſt be made from the under ſurface to the table. When it is well charged it begins to move; the bullet neareſt to a pillar moves towards the thimble on that pillar, and paſſing by electrifies it, and then puſhes itſelf from it; the ſucceeding bullet, which communicates with the other ſurface of the glaſs, more ſtrongly attracts that thimble on account of its being be-

fore

fore electrified by the other bullet; and thus the wheel encreases its motion till it comes to such a height as that the resistance of the air regulates it. It will go half an hour, and make one minute with another twenty turns in a minute, which is six hundred turns in the whole; the bullet of the upper surface giving in each turn twelve sparks, to the thimbles, which makes seven thousand two hundred sparks; and the bullet of the under surface receiving as many from the thimbles; those bullets moving in the time near two thousand five hundred feet.—The thimbles are well fixed, and in so exact a circle, that the bullets may pass within a very small distance of each of them.—If instead of two bullets you put eight, four communicating with the upper surface, and four with the under surface, placed alternately; which eight, at about six inches distance, completes the circumference, the force and swiftness will be greatly increased, the wheel making fifty turns in a minute; but then it will not continue moving so long.——These wheels may be applied, perhaps, to the ringing of chimes, and moving of light-made Orreries.

23. A small wire bent circularly with a loop at each end; let one end rest against the under surface of the wheel, and bring the other end nearer the upper surface, it will give a terrible crack, and the force will be discharged.

24. Every spark in that manner drawn from the surface of the wheel, makes a round hole in the gilding, tearing off a part of it in coming out; which shews that the fire is

is not accumulated on the gilding, but is in the glaſs itſelf.

25. The gilding being varniſhed over with turpentine varniſh, the varniſh, tho' dry and hard, is burnt by the ſpark drawn thro' it, and gives a ſtrong ſmell and viſible ſmoke. And when the ſpark is drawn thro' paper, all round the hole made by it, the paper will be blacked by the ſmoke, which ſometimes penetrates ſeveral of the leaves. Part of the gilding torn off, is alſo found forcibly driven into the hole made in the paper by the ſtroke.

26. 'Tis amazing to obſerve in how ſmall a portion of glaſs a great electrical force may lie. A thin glaſs bubble, about an inch diameter, weighing only ſix grains, being half filled with water, partly gilt on the outſide, and furniſh'd with a wire hook, gives, when electrified, as great a ſhock as a man can well bear. As the glaſs is thickeſt near the orifice, I ſuppoſe the lower half, which being gilt was electrified, and gave the ſhock, did not exceed two grains; for it appeared, when broke, much thinner than the upper half.—If one of theſe thin bottles be electrified by the coating, and the ſpark taken out thro' the gilding, it will break the glaſs inwards at the ſame time that it breaks the gilding outwards.

27. And allowing (for the reaſons before given, §. 8, 9, 10.) that there is no more electrical fire in a bottle after charging, than before, how great muſt be the quantity in this ſmall portion of glaſs! It ſeems as if it were of its very ſubſtance and eſſence. Perhaps if that due quantity of

electrical

electrical fire ſo obſtinately retained by glaſs, could be ſeparated from it, it would no longer be glaſs; it might loſe its tranſparency, or its brittleneſs, or its elaſticity.—— Experiments may poſſibly be invented hereafter, to diſcover this.

27. We were ſurpriſed at the account given in Mr *Watſon*'s book, of a ſhock communicated through a great ſpace of dry ground, and ſuſpect there muſt be ſome metaline quality in the gravel of that ground; having found that ſimple dry earth, rammed in a glaſs tube, open at both ends, and a wire hook inſerted in the earth at each end, the earth and wires making part of a circle, would not conduct the leaſt perceptible ſhock, and indeed when one wire was electrify'd, the other hardly ſhowed any ſigns of its being in connection with it.—Even a thoroughly wet pack-thread ſometimes fails of conducting a ſhock, tho' it otherwiſe conducts electricity very well. A dry cake of ice, or an icicle held between two in a circle, likewiſe prevents the ſhock; which one would not expect, as water conducts it ſo perfectly well.—Gilding on a new book, tho' at firſt it conducts the ſhock extremely well, yet fails after ten or a dozen experiments, though it appears otherwiſe in all reſpects the ſame, which we cannot account for.

28. There is one experiment more which ſurprizes us, and is not hitherto ſatisfactorily accounted for; it is this: Place an iron ſhot on a glaſs ſtand, and let a ball of damp cork, ſuſpended by a ſilk thread, hang in contact with the

ſhot. Take a bottle in each hand, one that is electrify'd through the hook, the other through the coating: Apply the giving wire to the ſhot, which will electrify it *poſitively*, and the cork ſhall be repelled: then apply the requiring wire, which will take out the ſpark given by the other; when the cork will return to the ſhot: Apply the ſame again, and take out another ſpark, ſo will the ſhot be electrify'd *negatively*; and the cork in that caſe ſhall be repelled equally as before. Then apply the giving wire to the ſhot, and give the ſpark it wanted, ſo will the cork return: Give it another, which will be an addition to its natural quantity, ſo will the cork be repelled again: And ſo may the experiment be repeated as long as there is any charge in the bottles. Which ſhews that bodies having leſs than the common quantity of Electricity, repel each other, as well as thoſe that have more.

Chagrined a little that we have hitherto been able to produce nothing in this way of uſe to mankind; and the hot weather coming on, when electrical experiments are not ſo agreeable, 'tis propoſed to put an end to them for this ſeaſon, ſomewhat humorouſly, in a party of pleaſure, on the banks of *Skuylkil* *. Spirits, at the ſame time, are to be fired by a ſpark ſent from ſide to ſide through the river, without any other conductor than the water; an experiment which we ſome time ſince performed, to the

* The river that waſhes one ſide of *Philadelphia*, as the *Delaware* does the other; both are ornamented with the ſummer habitations of the citizens, and the agreeable manſions of the principle people of this colony.

amazement

amazement of many. A turkey is to be killed for our dinner by the *electrical ſhock*, and roaſted by the *electrical jack*, before a fire kindled by the *electrified bottle*; when the healths of all the famous electricians in *England*, *Holland*, *France*, and *Germany*, are to be drank in * *electrified bumpers*, under the diſcharge of guns from the *electrical battery*.

* An *electrified bumper* is a ſmall thin glaſs tumbler, near filled with wine, and electrified as the bottle. This when brought to the lips gives a ſhock, if the party be cloſe ſhaved, and does not breathe on the liquor.

April 29,
1749.

LETTER IV.

CONTAINING

OBSERVATIONS *and* SUPPOSITIONS, *towards forming a new* HYPOTHESIS, *for explaining the ſeveral* Phænomena *of* THUNDER GUSTS*.

S I R,

§. 1. NON-ELECTRIC bodies, that have electric fire thrown into them, will retain it till other non-electrics, that have leſs, approach; and then 'tis communicated by a ſnap, and becomes equally divided.

2. Electrical fire loves water, is ſtrongly attracted by it, and they can ſubſiſt together.

3. Air is an electric *per ſe*, and when dry will not conduct the electrical fire; it will neither receive it, nor give

* Thunder-guſts are ſudden ſtorms of thunder and lightning, which are frequently of ſhort duration, but ſometimes produce miſchievous effects.

it

it to other bodies; otherwiſe no body ſurrounded by air could be electrified poſitively and negatively: for ſhould it be attempted poſitively, the air would immediately take away the overplus; or negatively, the air would ſupply what was wanting.

4. Water being electrified, the vapours ariſing from it will be equally electrified; and floating in the air, in the form of clouds, or otherwiſe, will retain that quantity of electrical fire, till they meet with other clouds or bodies not ſo much electrified, and then will communicate as before mentioned.

5. Every particle of matter electrified is repelled by every other particle equally electrified. Thus the ſtream of a fountain, naturally denſe and continual, when electrified, will ſeparate and ſpread in the form of a bruſh, every drop endeavouring to recede from every other drop. But on taking out the electrical fire, they cloſe again.

6. Water being ſtrongly electrified (as well as when heated by common fire) riſes in vapours more copiouſly; the attraction of coheſion among its particles being greatly weakened, by the oppoſite power of repulſion introduced with the electrical fire; and when any particle is by any means diſengaged, 'tis immediately repelled, and ſo flies into the air.

7. Particles happening to be ſituated as *A* and *B*, are more eaſily diſengaged than *C* and *D*, as each is held by contact with three only, whereas *C* and *D* are each in contact with nine. When the ſurface of water has the

leaſt

leaſt motion, particles are continually puſhed into the ſituation repreſented by *A* and *B*, FIG. 6.

8. Friction between a non-electric and an electric *per ſe* will produce electrical fire; not by *creating*, but *collecting* it: for it is equally diffuſed in our walls, floors, earth, and the whole maſs of common matter. Thus the whirling glaſs globe, during its friction againſt the cuſhion, draws fire from the cuſhion, the cuſhion is ſupplied from the frame of the machine, that from the floor on which it ſtands. Cut off the communication by thick glaſs or wax placed under the cuſhion, and no fire can be *produced*, becauſe it cannot be *collected*.

9. The Ocean is a compound of water, a non-electric, and ſalt an electric *per ſe*.

10. When there is a friction among the parts near its ſurface, the electrical fire is collected from the parts below. It is then plainly viſible in the night; it appears at the ſtern and in the wake of every ſailing veſſel; every daſh of an oar ſhows it, and every ſurff and ſpray: in ſtorms the whole ſea ſeems on fire.—The detach'd particles of water then repelled from the electrified ſurface, continually carry off the fire as it is collected; they riſe, and form clouds, and thoſe clouds are highly electrified, and retain the fire till they have an opportunity of communicating it.

11. The particles of water riſing in vapours, attach themſelves to particles of air.

12. The particles of air are ſaid to be hard, round, ſeparate and diſtant from each other; every particle ſtrongly

repelling

repelling every other particle, whereby they recede from each other, as far as common gravity will permit.

13. The ſpace between any three particles equally repelling each other, will be an equilateral triangle.

14. In air compreſſed, theſe triangles are ſmaller; in rarified air they are larger.

15. Common fire joined with air, increaſes the repulſion, enlarges the triangles, and thereby makes the air ſpecifically lighter. Such air, among denſer air, will riſe.

16. Common fire, as well as electrical fire, gives repulſion to the particles of water, and deſtroys their attraction of coheſion; hence common fire, as well as electrical fire, aſſiſts in raiſing vapours.

17. Particles of water, having no fire in them, mutually attract each other. Three particles of water then being attached to the three particles of a triangle of air, would by their mutual attraction operating againſt the air's repulſion, ſhorten the ſides and leſſen the triangle, whereby that portion of air being made denſer, would ſink to the earth with its water, and not riſe to contribute to the formation of a cloud.

18. But if every particle of water attaching itſelf to air, brings with it a particle of common fire, the repulſion of the air being aſſiſted and ſtrengthened by the fire, more than obſtructed by the mutual attraction of the particles of water, the triangle dilates, and that portion of air becoming rarer and ſpecifically lighter riſes.

19. If the particles of water bring electrical fire when they

they attach themſelves to air, the repulſion between the particles of water electrified, joins with the natural repulſion of the air, to force its particles to a greater diſtance, whereby the triangles are dilated, and the air riſes, carrying up with it the water.

20. If the particles of water bring with them portions of *both ſorts* of fire, the repulſion of the particles of air is ſtill more ſtrengthened and increaſed, and the triangles farther enlarged.

21. One particle of air may be ſurrounded by twelve particles of water of equal ſize with itſelf, all in contact with it; and by more added to thoſe.

22. Particles of air thus loaded would be drawn nearer together by the mutual attraction of the particles of water, did not the fire, common or electrical, aſſiſt their repulſion.

23. If air thus loaded be compreſſed by adverſe winds, or by being driven againſt mountains, *&c.* or condenſed by taking away the fire that aſſiſted it in expanding; the triangles contract, the air with its water will deſcend as a dew; or, if the water ſurrounding one particle of air comes in contact with the water ſurrounding another, they coaleſce and form a drop, and we have rain.

24. The ſun ſupplies (or ſeems to ſupply) common fire to all vapours, whether raiſed from earth or ſea.

25. Thoſe vapours which have both common and electrical fire in them, are better ſupported, than thoſe which have only common fire in them. For when vapours riſe

into

into the coldeſt region above the earth, the cold will not diminiſh the electrical fire, if it doth the common.

26. Hence clouds formed by vapours raiſed from freſh waters within land, from growing vegetables, moiſt earth, *&c.* more ſpeedily and eaſily depoſite their water, having but little electrical fire to repel and keep the particles ſeparate. So that the greateſt part of the water raiſed from the land is let fall on the land again; and winds blowing from the land to the ſea are dry; there being little uſe for rain on the ſea, and to rob the land of its moiſture, in order to rain on the ſea, would not appear reaſonable.

27. But clouds formed by vapours raiſed from the ſea, having both fires, and particularly a great quantity of the electrical, ſupport their water ſtrongly, raiſe it high, and being moved by winds, may bring it over the middle of the broadeſt continent from the middle of the wideſt ocean.

28. How theſe ocean clouds, ſo ſtrongly ſupporting their water, are made to depoſite it on the land where 'tis wanted, is next to be conſidered.

29. If they are driven by winds againſt mountains, thoſe mountains being leſs electrified attract them, and on contact take away their electrical fire (and being cold, the common fire alſo;) hence the particles cloſe towards the mountains and towards each other. If the air was not much loaded, it only falls in dews on the mountain tops and ſides, forms ſprings, and deſcends to the vales in rivulets, which united make larger ſtreams and rivers. If much loaded, the electrical fire is at once taken from the

G whole

whole cloud; and, in leaving it, flashes brightly and cracks loudly; the particles instantly coalescing for want of that fire, and falling in a heavy shower.

30. When a ridge of mountains thus dams the clouds, and draws the electrical fire from the cloud first approaching it; that which next follows, when it comes near the first cloud, now deprived of its fire, flashes into it, and begins to deposite its own water; the first cloud again flashing into the mountains; the third approaching cloud, and all the succeeding ones, acting in the same manner as far back as they extend, which may be over many hundred miles of country.

31. Hence the continual storms of rain, thunder, and lightning on the east-side of the *Andes*, which running north and south, and being vastly high, intercept all the clouds brought against them from the *Atlantic* ocean by the trade winds, and oblige them to deposite their waters, by which the vast rivers *Amazons*, *La Plata*, and *Oroonoko* are formed, which return the water into the same sea, after having fertilized a country of very great extent.

32. If a country be plain, having no mountains to intercept the electrified clouds, yet it is not without means to make them deposite their water. For if an electrified cloud coming from the sea, meets in the air a cloud raised from the land, and therefore not electrified; the first will flash its fire into the latter, and thereby both clouds shall be made suddenly to deposite water.

33. The electrified particles of the first cloud close when they lose their fire; the particles of the other cloud

close in receiving it: in both, they have thereby an opportunity of coalefcing into drops.—The concuffion or jerk given to the air, contributes alfo to fhake down the water, not only from thofe two clouds but from others near them. Hence the fudden fall of rain immediately after flafhes of lightning.

34. To fhew this by an eafy experiment: Take two round pieces of pafteboard two inches diameter; from the center and circumference of each of them fufpend by fine filk threads eighteen inches long, feven fmall balls of wood, or feven peas equal in bignefs; fo will the balls appending to each pafteboard, form equal equilateral triangles, one ball being in the center, and fix at equal diftances from that, and from each other; and thus they reprefent particles of air. Dip both fets in water, and fome cohering to each ball, they will reprefent air loaded. Dexteroufly electrify'd one fet, and its balls will repel each other to a greater diftance, enlarging the triangles. Could the water fupported by the feven balls come into contact, it would form a drop or drops fo heavy as to break the cohefion it had with the balls, and fo fall. Let the two fets then reprefent two clouds, the one a fea cloud electrified, the other a land cloud. Bring them within the fphere of attraction, and they will draw towards each other, and you will fee the feparated balls clofe thus; the firft electrified ball that comes near an unelectrified ball by attraction joins it, and gives it fire; inftantly they feparate, and each flies to another ball of its own party, one to

give, the other to receive fire; and ſo it proceeds through both ſets, but ſo quick as to be in a manner inſtantaneous. In the colliſion they ſhake off and drop their water, which repreſents rain.

35. Thus when ſea and land clouds would paſs at too great a diſtance from the flaſh, they are attracted towards each other till within that diſtance; for the ſphere of electrical attraction is far beyond the diſtance of flaſhing.

36. When a great number of clouds from the ſea meet a number of clouds raiſed from the land, the electrical flaſhes appear to ſtrike in different parts; and as the clouds are joſtled and mixed by the winds, or brought near by the electrical attraction, they continue to give and receive flaſh after flaſh, till the electrical fire is equally diffuſed.

37. When the gun-barrel (in electrical experiments) has but little electrical fire in it, you muſt approach it very near with your knuckle, before you can draw a ſpark. Give it more fire, and it will give a ſpark at a greater diſtance. Two gun-barrels united, and as highly electrified, will give a ſpark at a ſtill greater diſtance. But if two gun-barrels electrified will ſtrike at two inches diſtance, and make a loud ſnap, to what a great diſtance may 10,000 acres of electrified cloud ſtrike and give its fire, and how loud muſt be that crack?

38. It is a common thing to ſee clouds at different heights paſſing different ways, which ſhews different currents of air, one under the other. As the air between the

tropics is rarified by the ſun, it raiſes, the denſer northern and ſouthern air preſſing into its place. The air ſo rarified and forced up, paſſes northward and ſouthward, and muſt deſcend in the polar regions, if it has no opportunity before, that the circulation may be carried on.

39. As currents of air, with the clouds therein, paſs different ways, 'tis eaſy to conceive how the clouds, paſſing over each other, may attract each other, and ſo come near enough for the electrical ſtroke. And alſo how electrical clouds may be carried within land very far from the ſea, before they have an opportnnity to ſtrike.

40. When the air, with its vapours raiſed from the ocean between the tropics, comes to deſcend in the polar regions, and to be in contact with the vapours ariſing there, the electrical fire they brought begins to be communicated, and is ſeen in clear nights, being firſt viſible where 'tis firſt in motion, that is, where the contact begins, or in the moſt northern part; from thence the ſtreams of light ſeem to ſhoot ſoutherly, even up to the zenith of northern countries. But tho' the light ſeems to ſhoot from the north ſoutherly, the progreſs of the fire is really from the ſouth northerly, its motion beginning in the north being the reaſon that 'tis there firſt ſeen.

For the electrical fire is never viſible but when in motion, and leaping from body to body, or from particle to particle thro' the air. When it paſſes thro' denſe bodies 'tis unſeen. When a wire makes part of the circle, in the exploſion of the electrical phial, the fire, though in great

quantity

quantity, paſſes in the wire inviſibly: but in paſſing along a chain, it becomes viſible as it leaps from link to link. In paſſing along leaf-gilding 'tis viſible: for the leaf-gold is full of pores; hold a leaf to the light and it appears like a net; and the fire is ſeen in its leaping over the vacancies.—And as when a long canal filled with ſtill water is opened at one end, in order to be diſcharged, the motion of the water begins firſt near the opened end, and proceeds towards the cloſe end, tho' the water itſelf moves from the cloſe towards the opened end: ſo the electrical fire diſcharged into the polar regions, perhaps from a thouſand leagues length of vaporiz'd air, appears firſt where 'tis firſt in motion, *i. e.* in the moſt northern part, and the appearance proceeds ſouthward, tho' the fire really moves northward. This is ſuppoſed to account for the *Aurora Borealis.*

41. When there is great heat on the land, in a particular region (the ſun having ſhone on it perhaps ſeveral days, while the ſurrounding countries have been ſcreen'd by clouds) the lower air is rarified and riſes, the cooler denſer air above deſcends; the clouds in that air meet from all ſides, and join over the heated place; and if ſome are electrified, others not, lightning and thunder ſucceed, and ſhowers fall. Hence thunder-guſts after heats, and cool air after guſts; the water and the clouds that bring it, coming from a higher and therefore a cooler region.

42. An electrical ſpark, drawn from an irregular body at ſome diſtance is ſcarce ever ſtrait, but ſhows crooked

and

and waving in the air. So do the flafhes of lightning; the clouds being very irregular bodies.

43. As electrified clouds pafs over a country, high hills and high trees, lofty towers, fpires, mafts of fhips, chimneys, *&c.* as fo many prominencies and points, draw the electrical fire, and the whole cloud difcharges there.

44. Dangerous, therefore, is it to take fhelter under a tree during a thunder-guft. It has been fatal to many, both men and beafts.

45. It is fafer to be in the open field for another reafon. When the cloaths are wet, if a flafh in its way to the ground fhould ftrike your head, it will run in the water over the furface of your body; whereas, if your cloaths were dry, it would go through the body.

Hence a wet rat cannot be killed by the exploding electrical bottle, when a dry rat may.

46. Common fire is in all bodies, more or lefs, as well as electrical fire. Perhaps they may be different modifications of the fame element; or they may be different elements. The latter is by fome fufpected.

47. If they are different things, yet they may and do fubfift together in the fame body.

48. When electrical fire ftrikes through a body, it acts upon the common fire contained in it, and puts that fire in motion; and if there be a fufficient quantity of each kind of fire, the body will be inflamed.

49. When the quantity of common fire in the body is fmall, the quantity of the electrical fire (or the electrical

ftroke)

ſtroke) ſhould be greater: if the quantity of common fire be great, leſs electrical fire ſuffices to produce the effect.

50. Thus ſpirits muſt be heated before we can fire them by the electrical ſpark. If they are much heated a ſmall ſpark will do; if not, the ſpark muſt be greater.

51. 'Till lately we could only fire warm vapours; but now we can burn hard dry roſin. And when we can procure greater electrical ſparks, we may be able to fire not only unwarm'd ſpirits, as lightning does, but even wood, by giving ſufficient agitation to the common fire contained in it, as friction we know will do.

52. Sulphureous and inflammable vapours ariſing from the earth, are eaſily kindled by lightning. Beſides what ariſe from the earth, ſuch vapours are ſent out by ſtacks of moiſt hay, corn, or other vegetables, which heat and reek. Wood rotting in old trees or buildings does the ſame. Such are therefore eaſily and often fired.

53. Metals are often melted by lightning, tho' perhaps not from heat in the lightning, not altogether from agitated fire in the metals.—For as whatever body can inſinuate itſelf between the particles of metal, and overcome the attraction by which they cohere (as ſundry menſtrua can) will make the ſolid become a fluid, as well as fire, yet without heating it: ſo the electrical fire, or lightning, creating a violent repulſion between the particles of the metal it paſſes thro', the metal is fuſed.

54. If you would, by a violent fire, melt off the end of a nail, which is half driven into a door, the heat given the

whole

whole nail before a part would melt, muſt burn the board it ſticks in. And the melted part would burn the floor it dropp'd on. But if a ſword can be melted in the ſcabbard, and money in a man's pocket, by lightning, without burning either, it muſt be a cold fuſion.

55. Lightning rends ſome bodies. The electrical ſpark will ſtrike a hole thro' a quire of ſtrong paper.

56. If the ſource of lightning, aſſigned in this paper, be the true one, there ſhould be little thunder heard at ſea far from land. And accordingly ſome old ſea-captains, of whom enquiry has been made, do affirm, that the fact agrees perfectly with the hypotheſis; for that, in croſſing the great ocean, they ſeldom meet with thunder till they come into ſoundings; and that the iſlands far from the continent have very little of it. And a curious obſerver, who lived 13 years at *Bermudas*, ſays, there was leſs thunder there in that whole time than he has ſometimes heard in a month at *Carolina*.

ADDITIONAL PAPERS

TO

PETER COLLINSON, Esq; F. R. S. *London.*

SIR, PHILADELPHIA, *July* 29, 1750.

AS you first put us on electrical experiments, by sending to our library company a tube, with directions how to use it; and as our honourable proprietary enabled us to carry those experiments to a greater height, by this generous present of a compleat electrical apparatus; 'tis fit that both should know from time to time what progress we make. It was in this view I wrote and sent you my former papers on this subject, desiring, that as I had not the honour of a direct correspondence with that bountiful benefactor to our library, they might be communicated to him through your hands. In the same view I write, and send you this additional paper. If it happens to bring you nothing new (which may well be, considering the number of ingenious men in *Europe*, continually engaged in the same researches) at least it will show, that the instruments put into our hands, are not neglected; and, that if no valuable discoveries are made by us, whatever the cause may be, it is not want of industry and application.

I am, Sir,

Your much obliged

Humble Servant,

B. FRANKLIN.

OPINIONS *and* CONJECTURES,

concerning the Properties and Effects of the electrical Matter, arising from Experiments and Observations, made at Philadelphia, 1749.

§. 1. THE electrical matter consists of particles extremely subtile, since it can permeate common matter, even the densest metals, with such ease and freedom, as not to receive any perceptible resistance.

2. If any one should doubt, whether the electrical matter passes thro' the substance of bodies, or only over and along their surfaces, a shock from an electrified large glass jar, taken through his own body, will probably convince him.

3. Electrical matter differs from common matter in this, that the parts of the latter mutually attract, those of the former mutually repel, each other. Hence the appearing divergency in a stream of electrified effluvia.

4. But though the particles of electrical matter do repel each other, they are strongly attracted by all other matter.*

* See the ingenious essays on Electricity in the Transactions, by Mr *Ellicot*.

5. From these three things, the extreme subtility of the electrical matter, the mutual repulsion of its parts, and the strong attraction between them and other matter, arise this effect, that when a quantity of electrical matter is applied to a mass of common matter, of any bigness or length within our observation (which has not already got its quantity) it is immediately and equally diffused through the whole.

6. Thus common matter is a kind of spunge to the electrical fluid. And as a spunge would receive no water, if the parts of water were not smaller than the pores of the spunge; and even then but slowly, if there were not a mutual attraction between those parts and the parts of the spunge; and would still imbibe it faster, if the mutual attraction among the parts of the water did not impede, some force being required to separate them, and fastest; if, instead of attraction, there were a mutual repulsion among those parts, which would act in conjunction with the attraction of the spunge. So is the case between the electrical and common matter.

7. But in common matter there is (generally) as much of the electrical, as it will contain within its substance. If more is added, it lies without upon the surface, and forms, what we call an electrical atmosphere: and then the body is said to be electrified.

8. 'Tis supposed, that all kinds of common matter do not attract and retain the electrical, with equal strength and force; for reasons to be given hereafter. And that those

called electrics *per ſe*, as glaſs, &c. attract and retain it ſtrongeſt, and contain the greateſt quantity.

9. We know that the electrical fluid is *in* common matter, becauſe we can pump it *out* by the globe or tube. We know that common matter has near as much as it can contain, becauſe, when we add a little more to any portion of it, the additional quantity does not enter, but forms an electrical atmoſphere. And we know that common matter has not (generally) more than it can contain, otherwiſe all looſe portions of it would repel each other, as they conſtantly do when they have electric atmoſpheres.

10. The beneficial uſes of this electrical fluid in the creation, we are not yet well acquainted with, though doubtleſs ſuch there are, and thoſe very conſiderable; but we may ſee ſome pernicious conſequences, that would attend a much greater proportion of it. For had this globe we live on as much of it in proportion as we can give to a globe of iron, wood, or the like, the particles of duſt and other light matters that get looſe from it, would, by virtue of their ſeparate electrical atmoſpheres, not only repel each other, but be repelled from the earth, and not eaſily be brought to unite with it again; whence our air would continually be more and more clogged with foreign matter, and grow unfit for reſpiration. This affords another occaſion of adoring that wiſdom which has made all things by weight and meaſure!

11. If a piece of common matter be ſuppoſed entirely free from electrical matter, and a ſingle particle of the

latter

latter be brought nigh, 'twill be attracted and enter the body, and take place in the center, or where the attraction is every way equal. If more particles enter, they take their places where the balance is equal between the attraction of the common matter and their own mutual repulsion. 'Tis supposed they form triangles, whose sides shorten as their number increases; 'till the common matter has drawn in so many, that its whole power of compressing those triangles by attraction, is equal to their whole power of expanding themselves by repulsion; and then will such piece of matter receive no more.

12. When part of this natural proportion of electrical fluid is taken out of a piece of common matter, the triangles formed by the remainder, are supposed to widen by the mutual repulsion of the parts, until they occupy the whole piece.

13. When the quantity of electrical fluid taken from a piece of common matter is restored again, it enters, the expanded triangles being again compressed till there is room for the whole.

14. To explain this: take two apples, or two balls of wood or other matter, each having its own natural quantity of the electrical fluid. Suspend them by silk lines from the cieling. Apply the wire of a well-charged vial, held in your hand, to one of them (A) *Fig.* 7. and it will receive from the wire a quantity of the electrical fluid; but will not imbibe it, being already full. The fluid therefore will flow round its surface, and form an electrical atmosphere.

Bring

Bring A into contact with B, and half the electrical fluid is communicated, so that each has now an electrical atmosphere, and therefore they repel each other. Take away these atmospheres by touching the balls, and leave them in their natural state: then, having fixed a stick of sealing-wax to the middle of the vial to hold it by, apply the wire to A, at the same time the coating touches B. Thus will a quantity of the electrical fluid be drawn out of B, and thrown on A. So that A will have a redundance of this fluid, which forms an atmosphere round it, and B an exactly equal deficiency. Now bring these balls again into contact, and the electrical atmosphere will not be divided between A and B, into two smaller atmospheres as before; for B will drink up the whole atmosphere of A, and both will be found again in their natural state.

15. The form of the electrical atmosphere is that of the body it surrounds. This shape may be rendered visible in a still air, by raising a smoke from dry rosin, dropt into a hot tea-spoon under the electrised body, which will be attracted and spread itself equally on all sides, covering and concealing the body. And this form it takes, because it is attracted by all parts of the surface of the body, tho' it cannot enter the substance already replete. Without this attraction it would not remain round the body, but dissipate in the air.

16. The atmosphere of electrical particles surrounding an electrified sphere, is not more disposed to leave it or

more

more eaſily drawn off from any one part of the ſphere than from another, becauſe it is equally attracted by every part. But that is not the caſe with bodies of any other figure. From a cube it is more eaſily drawn at the corners than at the plane ſides, and ſo from the angles of a body of any other form, and ſtill moſt eaſily from the angle that is moſt acute. Thus if a body ſhaped as A,B,C,D,E, in Fig. 8. be electrified, or have an electrical atmoſphere communicated to it, and we conſider every ſide as a baſe on which the particles reſt, and by which they are attracted, one may ſee, by imagining a line from A to F, and another from E to G, that the portion of the atmoſphere included in F, A, E, G, has the line A, E, for its baſis. So the portion of atmoſphere included in H, A, B, I, has the line A, B, for its baſis. And likewiſe the portion included in K, B, C, L, has B, C, to reſt on; and ſo on the other ſide of the figure. Now if you would draw off this atmoſphere with any blunt ſmooth body, and approach the middle of the ſide A, B, you muſt come very near before the force of your attracter exceeds the force or power with which that ſide holds its atmoſphere. But there is a ſmall portion between I, B, K, that has leſs of the ſurface to reſt on, and to be attracted by, than the neighbouring portions, while at the ſame time there is a mutual repulſion between its particles and the particles of thoſe portions, therefore here you can get it with more eaſe, or at a greater diſtance. Between F, A, H, there is a larger portion that has yet a leſs ſurface to reſt on and to attract it; here

here therefore you can get it away ſtill more eaſily. But eaſieſt of all between L,C,M, where the quantity is largeſt, and the ſurface to attract and keep it back the leaſt. When you have drawn away one of theſe angular portions of the fluid, another ſucceeds in its place, from the nature of fluidity and the mutual repulſion beforementioned; and ſo the atmoſphere continues flowing off at ſuch angle, like a ſtream, till no more is remaining. The extremities of the portions of atmoſphere over theſe angular parts are likewiſe at a greater diſtance from the electrified body, as may be ſeen by the inſpection of the above figure; the point of the atmoſphere of the angle C, being much farther from C, than any other part of the atmoſphere over the lines C, B, or B, A: And, beſides the diſtance ariſing from the nature of the figure, where the attraction is leſs, the particles will naturally expand to a greater diſtance by their mutual repulſion. On theſe accounts we ſuppoſe electrified bodies diſcharge their atmoſpheres upon unelectrified bodies more eaſily and at a greater diſtance from their angles and points than from their ſmooth ſides.— Thoſe points will alſo diſcharge into the air, when the body has too great an electrical atmoſphere, without bringing any non-electric near, to receive what is thrown off: For the air, though an electric *per ſe*, yet has always more or leſs water and other non-electric matters mixed with it; and theſe attract and receive what is ſo diſcharged.

17. But points have a property, by which they *draw on* as well as *throw off* the electrical fluid, at greater diſtances

thau blunt bodies can. That is, as the pointed part of an electrified body will difcharge the atmofphere of that body, or communicate it fartheft to another body, fo the point of an unelectrified body, will draw off the electrical atmofphere from an electrified body, farther than a blunter part of the fame unelectrified body will do. Thus a pin held by the head, and the point prefented to an electrified body, will draw off its atmofphere at a foot diftance; where, if the head were prefented inftead of the point, no fuch effect would follow. To underftand this, we may confider, that if a perfon ftanding on the floor would draw off the electrical atmofphere from an electrified body, an iron crow and a blunt knitting-needle held alternately in his hand and prefented for that purpofe, do not draw with different forces in proportion to their different maffes. For the man, and what he holds in his hand, be it large or fmall, are connected with the common mafs of unelectrified matter; and the force with which he draws is the fame in both cafes, it confifting in the different proportion of electricity in the electrified body and that common mafs. But the force with which the electrified body retains its atmofphere by attracting it, is proportioned to the furface over which the particles are placed; *i. e.* four fquare inches of that furface retain their atmofphere with four times the force that one fquare inch retains its atmofphere. And as in plucking the hairs from the horfe's tail, a degree of ftrength fufficient to pull away a handful at once, could yet eafily ftrip it hair by hair; fo a blunt body

body preſented cannot draw off a number of particles at once, but a pointed one, with no greater force, takes them away eaſily, particle by particle.

18. Theſe explanations of the power and operation of points, when they firſt occurr'd to me, and while they firſt floated in my mind, appeared perfectly ſatisfactory; but now I have wrote them, and conſidered them more cloſely in black and white, I muſt own I have ſome doubts about them: yet, as I have at preſent nothing better to offer in their ſtead, I do not croſs them out: for even a bad ſolution read, and its faults diſcovered, has often given riſe to a good one in the mind of an ingenious reader.

19. Nor is it of much importance to us, to know the manner in which nature executes her laws; 'tis enough if we know the laws themſelves. 'Tis of real uſe to know, that china left in the air unſupported will fall and break; but *how* it comes to fall, and *why* it breaks, are matters of ſpeculation. 'Tis a pleaſure indeed to know them, but we can preſerve our china without it.

20. Thus in the preſent caſe, to know this power of points, may poſſibly be of ſome uſe to mankind, though we ſhould never be able to explain it. The following experiments, as well as thoſe in my firſt paper, ſhow this power. I have a large prime conductor made of ſeveral thin ſheets of Fuller's paſteboard form'd into a tube, near ten feet long and a foot diameter. It is cover'd with *Dutch* emboſs'd paper, almoſt totally gilt. This large

metallic ſurface ſupports a much greater electrical atmoſphere than a rod of iron of 50 times the weight would do. It is ſuſpended by ſilk lines, and when charged will ſtrike at near two inches diſtance, a pretty hard ſtroke, ſo as to make one's knuckle ach. Let a perſon ſtanding on the floor preſent the point of a needle at 12 or more inches diſtance from it, and while the needle is ſo preſented, the conductor cannot be charged, the point drawing off the fire as faſt as it is thrown on by the electrical globe. Let it be charged, and then preſent the point at the ſame diſtance, and it will ſuddenly be diſcharged. In the dark you may ſee a light on the point, when the experiment is made. And if the perſon holding the point ſtands upon wax, he will be electrified by receiving the fire at that diſtance. Attempt to draw off the electricity with a blunt body, as a bolt of iron round at the end, and ſmooth (a ſilverſmith's iron punch, inch thick, is what I uſe) and you muſt bring it within the diſtance of three inches before you can do it, and then it is done with a ſtroke and crack. As the paſteboard tube hangs looſe on ſilk lines, when you approach it with the punch iron, it likewiſe will move towards the punch, being attracted while it is charged; but if, at the ſame inſtant, a point be preſented as before, it retires again, for the point diſcharges it. Take a pair of large braſs ſcales, of two or more feet beam, the cords of the ſcales being ſilk. Suſpend the beam by a packthread from the cieling, ſo that the bottom of the ſcales may be about a foot from the

floor:

floor: The ſcales will move round in a circle by the untwiſting of the packthread. Set the iron punch on the end upon the floor, in ſuch a place as that the ſcales may paſs over it in making their circle: Then electrify one ſcale by applying the wire of a charged phial to it. As they move round, you ſee that ſcale draw nigher to the floor, and dip more when it comes over the punch; and if that be placed at a proper diſtance, the ſcale will ſnap and diſcharge its fire into it. But if a needle be ſtuck on the end of the punch, its point upwards, the ſcale, inſtead of drawing nigh to the punch, and ſnapping, diſcharges its fire ſilently through the point, and riſes higher from the punch. Nay, even if the needdle be placed upon the floor near the punch, its point upwards, the end of the punch, tho' ſo much higher than the needle, will not attract the ſcale and receive its fire, for the needle will get it and convey it away, before it comes nigh enough for the punch to act. And this is conſtantly obſervable in theſe experiments, that the greater quantity of electricity on the paſteboard tube, the farther it ſtrikes or diſcharges its fire, and the point likewiſe will draw it off at a ſtill greater diſtance.

Now if the fire of electricity and that of lightning be the ſame, as I have endeavoured to ſhow at large, in a former paper, this paſteboard tube and theſe ſcales may repreſent electrified clouds. If a tube of only ten feet long will ſtrike and diſcharge its fire on the punch at two or three inches diſtance, an electrified cloud of perhaps

haps 10,000 acres, may ſtrike and diſcharge on the earth at a proportionably greater diſtance. The horizontal motion of the ſcales over the floor, may repreſent the motion of the clouds over the earth; and the erect iron punch, a hill or high building; and then we ſee how electrified clouds paſſing over hills or high builders at too great a height to ſtrike, may be attracted lower till within their ſtriking diſtance. And laſtly, if a needle fix'd on the punch with its point upright, or even on the floor below the punch, will draw the fire from the ſcale ſilently at a much greater than the ſtriking diſtance, and ſo prevent its deſcending towards the punch; or if in its courſe it would have come nigh enough to ſtrike, yet being firſt deprived of its fire it cannot, and the punch is thereby ſecured from the ſtroke. I ſay, if theſe things are ſo, may not the knowledge of this power of points be of uſe to mankind, in preſerving houſes, churches, ſhips, *&c.* from the ſtroke of lightning, by directing us to fix on the higheſt parts of thoſe edifices, upright rods of iron made ſharp as a needle, and gilt to prevent ruſting, and from the foot of thoſe rods a wire down the outſide of the building into the ground, or down round one of the ſhrouds of a ſhip, and down her ſide till it reaches the water? Would not theſe pointed rods probably draw the electrical fire ſilently out of a cloud before it came nigh enough to ſtrike, and thereby ſecure us from that moſt ſudden and terrible miſchief?

21. To determine the queſtion, whether the clouds that

that contain lightning are electrified or not, I would propose an experiment to be try'd where it may be done conveniently. On the top of some high tower or steeple, place a kind of sentry-box, (as in FIG. 9.) big enough to contain a man and an electrical stand. From the middle of the stand, let an iron rod rise and pass bending out of the door, and then upright 20 or 30 feet, pointed very sharp at the end. If the electrical stand be kept clean and dry, a man standing on it when such clouds are passing low, might be electrified and afford sparks, the rod drawing fire to him from a cloud. If any danger to the man should be apprehended (though I think there would be none) let him stand on the floor of his box, and now and then bring near to the rod the loop of a wire that has one end fastened to the leads, he holding it by a wax handle; so the sparks, if the rod is electrified, will strike from the rod to the wire, and not affect him.

22. Before I leave this subject of lightning, I may mention some other similarities between the effects of that, and these of electricity. Lightning has often been known to strike people blind. A pigeon that we struck dead to appearance by the electrical shock, recovering life, droop'd about the yard several days, eat nothing though crumbs were thrown to it, but declined and died. We did not think of its being deprived of sight; but afterwards a pullet struck dead in like manner, being recovered by repeatedly blowing into its lungs, when set down on the floor, ran headlong against the wall, and on examination appeared

appeared perfectly blind. Hence we concluded that the pigeon alſo had been abſolutely blinded by the ſhock. The biggeſt animal we have yet killed or try'd to kill with the electrical ſtroke, was a well-grown pullet.

23. Reading in the ingenious Dr. *Hales*'s account of the thunder ſtorm at *Stretham*, the effect of the lightning in ſtripping off all the paint that had covered a gilt moulding of a pannel of wainſcot, without hurting the reſt of the paint, I had a mind to lay a coat of paint over the filleting of gold on the cover of a book, and try the effect of a ſtrong electrical flaſh ſent through that gold from a charged ſheet of glaſs. But having no paint at hand, I paſted a narrow ſtrip of paper over it; and when dry, ſent the flaſh through the gilding; by which the paper was torn off from end to end, with ſuch force, that it was broke in ſeveral places, and in others brought away part of the grain of the Turky-leather in which it was bound; and convinced me, that had it been painted, the paint would have been ſtript off in the ſame manner with that on the wainſcot at *Stretham*.

24. Lightning melts metals, and I hinted in my paper on that ſubject, that I ſuſpected it to be a cold fuſion; I do not mean a fuſion by force of cold, but a fuſion without heat. We have alſo melted gold, ſilver, and copper, in ſmall quantities, by the electrical flaſh. The manner is this: Take leaf gold, leaf ſilver, or leaf gilt copper, commonly called leaf braſs, or *Dutch* gold: cut off from the leaf long narrow ſtrips the breadth of

a ſtraw.

a ſtraw. Place one of theſe ſtrips between two ſtrips of ſmooth glaſs that are about the width of your finger. If one ſtrip of gold, the length of the leaf, be not long enough for the glaſs, add another to the end of it, ſo that you may have a little part hanging out looſe at each end of the glaſs. Bind the pieces of glaſs together from end to end with ſtrong ſilk thread; then place it ſo as to be part of an electrical circle, (the ends of gold hanging out being of uſe to join with the other parts of the circle) and ſend the flaſh through it, from a large electrified jar or ſheet of glaſs. Then if your ſtrips of glaſs remain whole, you will ſee that the gold is miſſing in ſeveral places, and inſtead of it a metallic ſtain on both the glaſſes; the ſtains on the upper and under glaſs exactly ſimilar in the minuteſt ſtroke, as may be ſeen by holding them to the light; the metal appeared to have been not only melted, but even vetrified, or otherwiſe ſo driven into the pores of the glaſs, as to be protected by it from the action of the ſtrongeſt *Aqua Fortis* or *Aqua Regia*. I ſend you encloſed two little pieces of glaſs with theſe metallic ſtains upon them, which cannot be removed without taking part of the glaſs with them. Sometimes the ſtain ſpreads a little wider than the breadth of the leaf, and looks brighter at the edge, as by inſpecting cloſely you may obſerve in theſe. Sometimes the glaſs breaks to pieces: once the upper glaſs broke into a thouſand pieces, looking like coarſe ſalt. Theſe pieces I ſend you were ſtain'd with *Dutch* gold. True gold makes a darker ſtain,

ſomewhat reddiſh; ſilver, a greeniſh ſtain. We once took two pieces of thick looking-glaſs, as broad as a Gunter's ſcale, and 6 inches long; and placing leaf-gold between them, put them betwixt two ſmoothly plain'd pieces of wood, and fix'd them tight in a book-binder's ſmall preſs; yet though they were ſo cloſely confined, the force ofthe electrical ſhock ſhivered the glaſs into many pieces. The gold was melted and ſtain'd into the glaſs as uſual. The circumſtances of the breaking of the glaſs differ much in making the experiment, and ſometimes it does not break at all: but this is conſtant, that the ſtains in the upper and under pieces are exact counterparts of each other. And though I have taken up the pieces of glaſs between my fingers immediately after this melting, I never could perceive the leaſt warmth in them.

25. In one of my former papers, I mention'd, that gilding on a book, though at firſt it communicated the ſhock perfectly well, yet fail'd after a few experiments, which we could not account for. We have ſince found, that one ſtrong ſhock breaks the continuity of the gold in the filleting, and makes it look rather like duſt of gold, abundance of its parts being broken and driven off; and it will ſeldom conduct above one ſtrong ſhock. Perhaps this may be the reaſon: When there is not a perfect continuity in the circle, the fire muſt leap over the vacancies; there is a certain diſtance which it is able to leap over according to its ſtrength; if a number of ſmall vacancies, though each be very minute, taken together

gether exceed that diſtance, it cannot leap over them, and ſo the ſhock is prevented.

26. From the before-mentioned law of electricity, that points, as they are more or leſs acute, draw on and throw off the electrical fluid with more or leſs power, and at greater or leſs diſtances, and in larger or ſmaller quantities in the ſame time, we may ſee how to account for the ſituation of the leaf of gold ſuſpended between two plates, the upper one continually electrified, the under one in a perſon's hand ſtanding on the floor. When the upper plate is electrified, the leaf is attracted and raiſed towards it, and would fly to that plate, were it not for its own points. The corner that happens to be uppermoſt when the leaf is riſing, being a ſharp point, from the extream thinneſs of the gold, draws and receives at a diſtance a ſufficient quantity of the electrical fluid to give itſelf an electrical atmoſphere, by which its progreſs to the upper plate is ſtopt, and it begins to be repelled from that place, and would be driven back to the under plate, but that its loweſt corner is likewiſe a point, and throws off or diſcharges the overplus of the leaf's atmoſphere, as faſt as the upper corner draws it on. Were theſe two points perfectly equal in acuteneſs, the leaf would take place exactly in the middle ſpace, for its weight is a trifle, compared to the power acting on it: But it is generally neareſt the unelectrified plate, becauſe, when the leaf is offered to the electrified plate at a diſtance, the ſharpeſt point is commonly firſt affected and raiſed towards it; ſo that point, from its greater

acuteneſs, receiving the fluid faſter than its oppoſite can diſcharge it at equal diſtances, it retires from the electrified plate, and draws nearer to the unelectrified plate, till it comes to a diſtance where the diſcharge can be exactly equal to the receipt, the latter being leſſened, and the former encreaſed; and there it remains as long as the globe continues to ſupply freſh electrical matter. This will appear plain, when the difference of acuteneſs in the corners is made very great. Cut a piece of *Dutch* gold (which is fitteſt for theſe experiments on account of its greater ſtrength) into the form of FIG. 10. the upper corner a right angle, the two next obtuſe angles, and the loweſt a very acute one; and bring this on your plate under the electrified plate, in ſuch a manner as that the right-angled part may be firſt raiſed (which is done by covering the acute part with the hollow of your hand) and you will ſee this leaf take place much nearer to the upper than the under plate; becauſe without being nearer, it cannot receive ſo faſt at its right-angled point, as it can diſcharge at its acute one. Turn this leaf with the acute part uppermoſt, and then it takes place neareſt the unelectrified plate; becauſe, otherwiſe it receives faſter at its acute point than it can diſcharge at its right-angled one. Thus the difference of diſtance is always proportioned to the difference of acuteneſs. Take care in cutting your leaf to leave no little ragged particles on the edges, which ſometimes form points where you would not have them. You may make this

figure

figure ſo acute below and blunt above, as to need no under plate, it diſcharging faſt enough into the air. When it is made narrower, as the figure between the pricked lines, we call it the *Golden Fiſh*, from its manner of acting. For if you take it by the tail, and hold it at a foot or greater horizontal diſtance from the prime conductor, it will, when let go, fly to it with a briſk but wavering motion, like that of an eel through the water; it will then take place under the prime conductor, at perhaps a quarter or half an inch diſtance, and keep a continual ſhaking of its tail like a fiſh, ſo that it ſeems animated. Turn its tail towards the prime conductor, and then it flies to your finger, and ſeems to nibble it. And if you hold a plate under it at ſix or eight inches diſtance, and ceaſe turning the globe, when the electrical atmoſphere of the conductor grows ſmall, it will deſcend to the plate and ſwim back again ſeveral times with the ſame fiſh-like motion, greatly to the entertainment of ſpectators. By a little practice in blunting or ſharpening the heads or tails of theſe figures, you may make them take place as deſired, nearer, or farther from the electrified plate.

27. It is ſaid in ſection 8, of this paper, that all kinds of common matter are ſuppoſed not to attract the electrical fluid with equal ſtrength; and that thoſe called electrics *per ſe*, as glaſs, &c. attract and retain it ſtrongeſt, and contain the greateſt quantity. This latter poſition may ſeem a paradox to ſome, being contrary to the hitherto received opinion; and therefore I ſhall now endeavour to explain it.

28. In

28. In order to this, let it firſt be conſider'd, *that we cannot by any means we are yet acquainted with, force the electrical fluid thro' glaſs.* I know it is commonly thought that it eaſily prevades glaſs, and the experiment of a feather ſuſpended by a thread in a bottle hermetically ſealed, yet moved by bringing a rubbed tube near the outſide of the bottle, is alledged to prove it. But, if the electrical fluid ſo eaſily pervades glaſs, how does the vial become *charged* (as we term it) when we hold it in our hands? Would not the fire thrown in by the wire paſs through to our hands, and ſo eſcape into the floor? Would not the bottle in that caſe be left juſt as we found it, uncharged, as we know a metal bottle ſo attempted to be charged would be? Indeed, if there be the leaſt crack, the minuteſt ſolution of continuity in the glaſs, though it remains ſo tight that nothing elſe we know of will paſs, yet the extremely ſubtile electrical fluid flies through ſuch a crack with the greateſt freedom, and ſuch a bottle we know can never be charged: What then makes the difference between ſuch a bottle and one that is ſound, but this, that the fluid can paſs through the one, and not through the other *?

29. It is true, there is an experiment that at firſt ſight would be apt to ſatisfy a ſlight obſerver, that the fire thrown into the bottle by the wire, does really paſs thro'

* See the firſt ſixteen Sections of the former paper, called *Farther Experiments*, &c.

the

the glafs. It is this: place the bottle on a glafs ftand, under the prime conductor; fufpend a bullet by a chain from the prime conductor, till it comes within a quarter of an inch right over the wire of the bottle; place your knuckle on the glafs ftand, at juft the fame diftance from the coating of the bottle, as the bullet is from its wire. Now let the globe be turned, and you fee a fpark ftrike from the bullet to the wire of the bottle, and the fame inftant you fee and feel an exactly equal fpark ftriking from the coating on your knuckle, and fo on fpark for fpark. This looks as if the whole received by the bottle was again difcharged from it. And yet the bottle by this means is charged! * And therefore the fire that thus leaves the bottle, though the fame in quantity, cannot be the very fame fire that entered at the wire; for if it were, the bottle would remain uncharged.

30. If the fire that fo leaves the bottle be not the fame that is thrown in through the wire, it muft be fire that fubfifted in the bottle, (that is, in the glafs of the bottle) before the operation began.

31. If fo, there muft be a great quantity in glafs, becaufe a great quantity is thus difcharged even from very thin glafs.

32. That this electrical fluid or fire is ftrongly attracted by glafs, we know from the quicknefs and violence with which it is refumed by the part that had been deprived of it,

* See Sect. 10. of *Farther Experiments*, &c.

it, when there is an opportunity. And by this, that we cannot from a mafs of glafs draw a quantity of electrical fire, or electrify the whole mafs *minus*, as we can a mafs of metal. We cannot leffen or increafe its whole quantity, for the quantity it has it holds; and it has as much as it can hold. Its pores are filled with it as full as the mutual repellency of the particles will admit; and what is already in, refufes, or ftrongly repels, any additional quantity. Nor have we any way of moving the electrical fluid in glafs, but one; that is, by covering part of the two furfaces of thin glafs with non-electrics, and then throwing an additional quantity of this fluid on one furface, which fpreading in the non-electric, and being bound by it to that furface, acts by its repelling force on the particles of the electrical fluid contained in the other furface, and drives them out of the glafs into the non-electric on that fide, from whence they are difcharged, and then thofe added on the charged fide can enter. But when this is done, there is no more in the glafs, nor lefs than before, juft as much having left it on one fide as it received on the other.

33. I feel a want of terms here, and doubt much whether I fhall be able to make this part intelligible. By the word *furface*, in this cafe, I do not mean mere length and breadth without thicknefs; but when I fpeak of the upper or under furface of a piece of glafs, the outer or inner furface of the vial, I mean length, breadth, and half the thicknefs, and beg the favour of being fo underftood. Now, I fuppofe, that glafs in its firft principles, and in the

furnace,

furnace, has no more of this electrical fluid than other common matter: That when it is blown, as it cools, and the particles of common fire leave it, its pores become a vacuum: That the component parts of glafs are extremely fmall and fine, I guefs from its never fhowing a rough face when it breaks, but always a polifh; and from the fmallnefs of its particles I fuppofe the pores between them muft be exceeding fmall, which is the reafon that aqua-fortis, nor any other menftruum we have, can enter to feparate them and diffolve the fubftance; nor is any fluid we know of, fine enough to enter, except common fire, and the electrical fluid. Now the departing fire leaving a vacuum, as aforefaid, between thefe pores, which air nor water are fine enough to enter and fill, the electrical fluid (which is every where ready in what we call the non-electrics, and in the non-electric Mixtures that are in the air) is attracted in: yet does not become fixed with the fubftance of the glafs, but fubfifts there as water in a porous ftone, retained only by the attraction of the fixed parts, itfelf ftill loofe and a fluid. But I fuppofe farther, that in the cooling of the glafs, its texture becomes clofeft in the middle, and forms a kind of partition, in which the pores are fo narrow, that the particles of the electrical fluid, which enter both furfaces at the fame time, cannot go through, or pafs and repafs from one furface to the other, and fo mix together; yet, though the particles of electrical fluid, imbibed by each furface, cannot themfelves

paſs through to thoſe of the other, their repellency can, and by this means they act on one another. The particles of the electrical fluid have a mutual repellency, but by the power of attraction in the glaſs they are condenſed or forced nearer to each other. When the glaſs has received, and, by its attraction, forced cloſer together ſo much of this electrical fluid, as that the power of attracting and condenſing in the one, is equal to the power of expanſion in the other, it can imbibe no more, and that remains its conſtant whole quantity; but each ſurface would receive more, if the repellencey of what is in the oppoſite ſurface did not reſiſt its entrance. The quantities of this fluid in each ſurface being equal, their repelling action on each other is equal; and therefore thoſe of one ſurface cannot drive out thoſe of the other: but, if a greater quantity is forced into one ſurface than the glaſs would naturally draw in; this increaſes the repelling power on that ſide, and overpowering the attraction on the other, drives out part of the fluid that had been imbibed by that ſurface, if there be any non-electric ready to receive it: ſuch there is in all caſes where glaſs is electrified to give a ſhock. The ſurface that has been thus emptied by having its electrical fluid driven out, reſumes again an equal quantity with violence, as ſoon as the glaſs has an opportunity to diſcharge that over quantity more than it could retain by attraction in its other ſurface, by the additional repellency of which the vacuum had been occaſioned. For experiments fa-

vouring

vouring (if I may not ſay confirming) this hypotheſis, I muſt, to avoid repetition, beg leave to refer you back to what is ſaid of the electrical phial in my former papers.

34. Let us now ſee how it will account for ſeveral other appearances.—Glaſs, a body extremely elaſtic (and perhaps its elaſticity may be owing in ſome degree to the ſubſiſting of ſo great a quantity of this repelling fluid in its pores) muſt, when rubbed, have its rubbed ſurface ſomewhat ſtretched, or its ſolid parts drawn a little farther aſunder, ſo that the vacancies in which the electrical fluid reſides, become larger, affording room for more of that fluid, which is immediately attracted into it from the cuſhion or hand rubbing, they being ſupply'd from the common ſtock. But the inſtant the parts of the glaſs ſo open'd and fill'd have paſs'd the friction, they cloſe again, and force the additional quantity out upon the ſurface, where it muſt reſt till that part comes round to the cuſhion again, unleſs ſome non-electric (as the prime conductor) firſt preſents to receive it.* But if the inſide of the globe be lined with a non-electric, the ad-

* In the dark the electrical fluid may be ſeen on the cuſhion in two ſemi-circles or half-moons, one on the fore part, the other on the back part of the cuſhion, juſt where the globe and cuſhion ſeparate. In the fore creſcent the fire is paſſing out of the cuſhion into the glaſs; in the other it is leaving the glaſs, and returning into the back part of the cuſhion. When the prime conductor is apply'd to take it off the glaſs, the back creſcent diſappears.

ditional repellency of the electrical fluid, thus collected by friction on the rubb'd part of the globe's outer ſurface, drives an equal quantity out of the inner ſurface into that non-electric lining, which receiving it, and carrying it away from the rubb'd part into the common maſs, through the axis of the globe and frame of the machine, the new collected electrical fluid can enter and remain in the outer ſurface, and none of it (or a very little) will be received by the prime conductor. As this charg'd part of the globe comes round to the cuſhion again, the outer ſurface delivers its overplus fire into the cuſhion, the oppoſite inner ſurface receiving at the ſame time an equal quantity from the floor. Every electrician knows that a globe wet within will afford little or no fire, but the reaſon has not before been attempted to be given, that I know of.

34. So if a tube lined with a * non-electric, be rubb'd, little or no fire is obtained from it. What is collected from the hand in the downward rubbing ſtroke, entering the pores of the glaſs, and driving an equal quantity out of the inner ſurface into the non-electric lining: and the hand in paſſing up to take a ſecond ſtroke, takes out again what had been thrown into the outer ſurface, and then the inner ſurface receives back again what it had given to the non-electric lining. Thus the particles of

* Gilt paper, with the gilt face next the glaſs, does well.

electrical fluid belonging to the inside surface go in and out of their pores every stroke given to the tube. Put a wire into the tube, the inward end in contact with the non-electric lining, so it will represent the *Leyden* bottle. Let a second person touch the wire while you rub, and the fire driven out of the inward surface when you give the stroke, will pass through him into the common mass, and return through him when the inner surface resumes its quantity, and therefore this new kind of *Leyden* bottle cannot so be charged. But thus it may: after every stroke, before you pass your hand up to make another, let the second person apply his finger to the wire, take the spark, and then withdraw his finger; and so on till he has drawn a number of sparks; thus will the inner surface be exhausted, and the outer surface charged; then wrap a sheet of gilt paper close round the outer surface, and grasping it in your hand you may receive a shock, by applying the finger of the other hand to the wire: for now the vacant pores in the inner surface resume their quantity, and the overcharg'd pores in the outer surface discharge that overplus; the equilibrium being restored through your body, which could not be restored through the glass.* If the tube be exhausted of air, a non-electric lining in contact with the wire is not necessary; for *in vacuo*, the electrical fire will fly freely from

* See *Farther Experiments*, §. 15.

the

the inner ſurface, without a non-electric conductor: but air reſiſts its motion; for being itſelf an electric *per ſe*, it does not attract it, having already its quantity. So the air never draws off an electric atmoſphere from any body, but in proportion to the non-electrics mix'd with it: it rather keeps ſuch an atmoſphere confin'd, which from the mutual repulſion of its particles, tends to diſſipation, and would immediately diſſipate *in vacuo*.—And thus the experiment of the feather incloſed in a glaſs veſſel hermetically ſealed, but moving on the approach of the rubbed tube, is explained: When an additional quantity of the electrical fluid is applied to the ſide of the veſſel by the atmoſphere of the tube, a quantity is repelled and driven out of the inner ſurface of that ſide into the veſſel, and there affects the feather, returning again into its pores, when the tube with its atmoſphere is withdrawn; not that the particles of that atmoſphere did themſelves paſs through the glaſs to the feather.——And every other appearance I have yet ſeen, in which glaſs and electricity are concern'd, are, I think, explained with equal eaſe by the ſame hypotheſis. Yet, perhaps, it may not be a true one, and I ſhall be obliged to him that affords me a better.

35. Thus I take the difference between non-electrics and glaſs, an electric *per ſe*, to conſiſt in theſe two particulars. 1ſt, That a non-electric eaſily ſuffers a change in the quantity of the electrical fluid it contains. You

may

may leſſen its whole quantity by drawing out a part, which the whole body will again reſume; but of glaſs you can only leſſen the quantity contained in one of its ſurfaces; and not that, but by ſupplying an equal quantity at the ſame time to the other ſurface; ſo that the whole glaſs may always have the ſame quantity in the two ſurfaces, their two different quantities being added together. And this can only be done in glaſs that is thin; beyond a certain thickneſs we have yet no power that can make this change. And, 2dly, that the electrical fire freely removes from place to place, in and through the ſubſtance of a non-electric, but not ſo through the ſubſtance of glaſs. If you offer a quantity to one end of a long rod of metal, it receives it, and when it enters, every particle that was before in the rod, puſhes its neighbour quite to the further end, where the overplus is diſcharged; and this inſtantaneouſly where the rod is part of the circle in the experiment of the ſhock. But glaſs, from the ſmallneſs of its pores, or ſtronger attraction of what it contains, refuſes to admit ſo free a motion; a glaſs rod will not conduct a ſhock, nor will the thinneſt glaſs ſuffer any particle entering one of its ſurfaces to paſs thro' to the other.

36. Hence we ſee the impoſſibility of ſucceſs, in the experiments propoſed, to draw out the effluvial virtues of a non-electric, as cinnamon for inſtance, and mixing them with the electrical fluid, to convey them with that into the

the body, by including it in the globe, and then applying friction, &c. For though the effluvia of cinnamon, and the electrical fluid ſhould mix within the globe, they would never come out together through the pores of the glaſs, and ſo go to the prime conductor; for the electrical fluid itſelf cannot come through; and the prime conductor is always ſupply'd from the cuſhion, and that from the floor. And beſides, when the globe is filled with cinnamon, or other non-electric, no electrical fluid can be obtained from its outer ſurface, for the reaſon before-mentioned. I have try'd another way, which I thought more likely to obtain a mixture of the electrical and other effluvia together, if ſuch a mixture had been poſſible. I placed a glaſs plate under my cuſhion, to cut off the communication between the cuſhion and floor; then brought a ſmall chain from the cuſhion into a glaſs of oil of turpentine, and carried another chain from the oil of turpentine to the floor, taking care that the chain from the cuſhion to the glaſs touch'd no part of the frame of the machine. Another chain was fixed to the prime conductor, and held in the hand of a perſon to be electrifed. The ends of the two chains in the glaſs were near an inch diſtant from each other, the oil of turpentine between. Now the globe being turn'd, could draw no fire from the floor through the machine, the communication that way being cut off by the thick glaſs plate under the cuſhion: it muſt then draw it through the

chains

chains whofe ends were dipt in the oil of turpentine. And as the oil of turpentine, being an electric *per fe*, would not conduct, what came up from the floor was obliged to jump from the end of one chain to the end of the other, through the fubftance of that oil, which we could fee in large fparks; and fo it had a fair opportunity of feizing fome of the fineft particles of the oil in its paffage, and carrying them off with it: but no fuch effect followed, nor could I perceive the leaft difference in the fmell of the electrical effluvia thus collected, from what it has when collected otherwife; nor does it otherwife affect the body of a perfon electrifed. I likewife put into a phial, inftead of water, a ftrong purgative liquid, and then charged the phial, and took repeated fhocks from it, in which cafe every particle of the electrical fluid muft, before it went through my body, have firft gone through the liquid when the phial is charging, and returned through it when difcharging, yet no other effect followed than if it had been charged with water. I have alfo fmelt the electrical fire when drawn thro' gold, filver, copper, lead, iron, wood, and the human body, and could perceive no difference; the odour is always the fame where the fpark does not burn what it ftrikes; and therefore I imagine it does not take that fmell from any quality of the bodies it paffes through. And indeed, as that fmell fo readily leaves the electrical matter, and adheres to the knuckle receiving the fparks, and to other

things; I fuſpect that it never was connected with it, but ariſes inſtantaneouſly from ſomething in the air acted upon by it. For if it was fine enough to come with the electrical fluid through the body of one perſon, why ſhould it ſtop on the ſkin of another?

But I ſhall never have done, if I tell you all my conjectures, thoughts, and imaginations, on the nature and operations of this electrical fluid, and relate the variety of little experiments we have try'd. I have already made this paper too long, for which I muſt crave pardon, not having now time to make it ſhorter. I ſhall only add, that as it has been obſerved here that ſpirits will fire by the electrical ſpark in the ſummer time, without heating them, when *Fahrenheit*'s thermometer is above 70; ſo when colder, if the operator puts a ſmall flat bottle of ſpirits in his boſom, or a cloſe pocket, with the ſpoon, ſome little time before he uſes them, the heat of his body will communicate warmth more than ſufficient for the purpoſe.

ADDI-

ADDITIONAL EXPERIMENT, *proving that the* Leyden Bottle *has no more electrical Fire in it when charged, than before; nor less when discharged: That, in discharging, the Fire does not issue from the Wire and the Coating at the same Time, as some have thought, but that the Coating always receives what is discharged by the Wire, or an equal Quantity; the outer Surface being always in a negative State of Electricity, when the inner Surface is in a positive State.*

PLACE a thick plate of glass under the rubbing cushion, to cut off the communication of electrical fire from the floor to the cushion; then, if there be no fine points or hairy threads sticking out from the cushion, or from the parts of the machine opposite to the cushion, (of which you must be careful) you can get but a few sparks from the prime conductor, which are all the cushion will part with.

Hang a phial then on the prime conductor, and it will not charge, tho' you hold it by the coating.——But

Form a communication by a chain from the coating to the cushion, and the phial will charge.

For the globe then draws the electrical fire out of the outside surface of the phial, and forces it, through the prime conductor and wire of the phial, into the inside surface.

Thus

Thus the bottle is charged with its own fire, no other being to be had while the glaſs plate is under the cuſhion.

Hang two cork balls by flaxen threads to the prime conductor; then touch the coating of the bottle, and they will be electrified and recede from each other.

For juſt as much fire as you give the coating, ſo much is diſcharged thro' the wire upon the prime conductor, whence the cork balls receive an electrical atmoſphere. But,

Take a wire bent in the form of a C, with a ſtick of wax fixed to the outſide of the curve, to hold it by; and apply one end of this wire to the coating, and the other at the ſame time to the prime conductor, the phial will be diſcharged; and if the balls are not electrified before the diſcharge, neither will they appear to be ſo after the diſcharge, for they will not repel each other.

Now if the fire diſcharged from the inſide ſurface of the bottle through its wire, remained on the prime conductor, the balls would be electrified and recede from each other.

If the phial really exploded at both ends, and diſcharged fire from both coating and wire, the balls would be *more* electrified, and recede *farther*; for none of the fire can eſcape, the wax handle preventing.

But if the fire, with which the inſide ſurface is ſurcharged, be ſo much preciſely as is wanted by the outſide ſurface, it will paſs round through the wire fixed to the wax handle,

handle, reſtore the equilibrium in the glaſs, and make no alteration in the ſtate of the prime conductor.

Accordingly we find, that if the prime conductor be electrified, and the cork balls in a ſtate of repellency before the bottle is charged, they continue ſo afterwards. If not, they are not electrified by that diſcharge.

CORRECTIONS *and* ADDITIONS *to the* Preceding Papers.

PAGE 2, Sect. 1. We ſince find, that the fire in the bottle is not contained in the non-electric, but *in the glaſs*. All that is after ſaid of the *top* and *bottom* of the bottle, is true of the *inſide* and *outſide* ſurfaces, and ſhould have been ſo expreſſed. *See* Sect. 16, p. 16.

Page 6, line 13. The equilibrium will ſoon be reſtored *but ſilently*, &c. This muſt have been a miſtake. When the bottle is full charged, the crooked wire cannot well be brought to touch the top and bottom ſo quick, but that there will be a loud ſpark; unleſs the points be ſharp without loops.

Ibid. line ult. *Outſide:* add, ſuch moiſture continuing up to the cork or wire.

Page 12, line 14. *By candle-light*, &c. From ſome obſervations ſince made, I am inclined to think, that it is not the light, but the ſmoke or non-electric effluvia from the

the candle, coal, and red-hot iron, that carry off the electrical fire, being firſt attracted and then repelled.

Page 13, line 15. *Windmill wheels*, &c. We afterwards diſcovered, that the afflux or efflux of the electrical fire, was not the cauſe of the motions of thoſe wheels, but various circumſtances of attraction and repulſion.

Page 16, line 21. *Let* A *and* B *ſtand on wax*, &c. We ſoon found that it was only neceſſary for one of them to ſtand on wax.

Page 24, line 12. r. contact, line 24. confined.

Page 25, line 10, for *ſtand* read *hand*.

Page 28, line 2. *The conſequence might perhaps be fatal*, &c. We have found it fatal to ſmall animals, but 'tis not ſtrong enough to kill large ones. The biggeſt we have killed is a hen.

Page 31, line 20. *Ringing of chimes*, &c. This is ſince done.

Page 33, line 22. *Fails after ten or twelve experiments.* This was by a ſmall bottle; and ſince found to fail after with a large glaſs.

Page 40, Sect. 50, 51. *Spirits muſt be heated before we can fire them*, &c. We have ſince fired ſpirits without heating, when the weather is warm.

F I N I S.

NEW EXPERIMENTS

AND

OBSERVATIONS

ON

ELECTRICITY.

MADE AT

Philadelphia in *America.*

BY

BENJAMIN FRANKLIN, *Esq*;

AND

Communicated in ſeveral Letters to P. COLLINSON, *Esq*; of *London*, F.R.S.

PART II.

The THIRD EDITION.

LONDON:

Printed by R. CAVE, at *St John's-Gate.* MDCCLXII.
(Price 6 *d.*)

LETTER V.

FROM

BENJAMIN FRANKLIN, *Esq*; of PHILADELPHIA.

TO

PETER COLLINSON, *Esq*; F. R. S. *at* London.

SIR, *July* 27, 1750.

MR *W-ts-n*, I believe, wrote his obſervations on my laſt paper in haſte, without having firſt well conſidered the experiments related §. 17. which ſtill appear to me deciſive in the queſtion,—*Whether the accumulation of the electrical fire be in the electrified glaſs, or in the non-electric matter connected with the glaſs?* And to demonſtrate that 'tis really in the glaſs.

As to the experiment that ingenious gentleman mentions, and which he thinks concluſive on the other ſide, I perſuade myſelf he will change his opinion of it, when he conſiders, that as one perſon applying the wire of the charged bottle to warm ſpirits, in a ſpoon held by another perſon, both ſtanding on the floor, will fire the ſpirits, and yet ſuch firing will not determine whether the accumula-

tion was in the glaſs or the non-electric; ſo the placing another perſon between them, ſtanding on wax, with a baſon in his hand, into which the water from the phial is pour'd, *while he at the inſtant of pouring* preſents a finger of his other hand to the ſpirits, does not at all alter the caſe; the ſtream from the phial, the ſide of the baſon, with the arms and body of the perſon on the wax, being all together but as one long wire, reaching from the internal ſurface of the phial to the ſpirits.

June 29, 1751. In Capt. *Waddel's* account of the effects of lightening on his ſhip, I could not but take notice of the large comazants (as he calls them) that ſettled on the ſpintles at the topmaſt heads, and burnt like very large torches (before the ſtroke). According to my opinion, the electrical fire was then drawing off, as by points, from the cloud; the largeneſs of the flame betokening the great quantity of electricity in the cloud: and had there been a good wire communication from the ſpintle heads to the ſea, that could have conducted more freely than tarred ropes, or maſts of turpentine wood, I imagine there would either have been no ſtroke; or, if a ſtroke, the wire would have conducted it all into the ſea without damage to the ſhip.

His compaſſes loſt the virtue of the load-ſtone, or the poles were revers'd; the North point turning to the South. —By electricity we have (*here* at *Philadelphia*) frequently given polarity to needles, and reverſed them at pleaſure.

Mr

Mr *Wilſon*, at *London*, tried it on two large maſſes, and with too ſmall force.

A ſhock from four large glaſs jars, ſent through a fine ſewing needle, gives it polarity, and it will traverſe when laid on water.—If the needle when ſtruck lies Eaſt and Weſt, the end entered by the electric blaſt points North. —If it lies North and South, the end that lay towards the North will continue to point North when placed on water, whether the fire entered at that end, or at the contrary end.

The polarity given is ſtrongeſt when the needle is ſtruck, lying North and South, weakeſt when lying Eaſt and Weſt; perhaps if the force was ſtill greater, the South end, enter'd by the fire, (when the needle lies North and South) might become the North, otherwiſe it puzzles us to account for the inverting of compaſſes by lightening; ſince their needles muſt always be found in that ſituation, and by our little experiments, whether the blaſt entered the North and went out at the South end of the needle, or the contrary, ſtill the end that lay to the North ſhould continue to point North.

In theſe experiments the ends of the needles are ſometimes finely blued like a watch ſpring by the electric flame. —This colour given by the flaſh from two jars only, will wipe off, but four jars fix it, and frequently melt the needles. I ſend you ſome that have had their heads and points melted off, by our mimic lightning; and a pin that had its point melted off, and ſome part of its head

and

and neck run. Sometimes the furface on the body of the needle is alfo run, and appears blifter'd when examin'd by a magnifying glafs: the jars I make ufe of hold 7 or 8 gallons, and are coated and lined with tin-foil; each of them takes a thoufand turns of a globe nine inches diameter to charge it.

I fend you two fpecimens of tin-foil melted between glafs, by the force of two jars only.

I have not heard that any of your *European* electricians have hitherto been able to fire gunpowder by the electric flame.—We do it here, in this manner.—A fmall cartridge is filled with dry powder, hard rammed, fo as to bruife fome of the grains, two pointed wires are then thruft in, one at each end, the points approaching each other in the middle of the cartridge till within the diftance of half an inch, then the cartridge being placed in the circle, when the four jars are difcharged, the electric flame leaping from the point of one wire to the point of the other, within the cartridge amongft the powder, *fires it*, and the explofion of the powder is at the fame inftant with the crack of the difcharge.

Yours, &c.

B. FRANKLIN.

LET-

LETTER VI.

FROM

BENJAMIN FRANKLIN, *Esq*; of *Philadelphia*.

TO

C. C. Esq; at *New York*.

SIR, 1751.

I Inclose you Answers, such as my present hurry of business will permit me to make, to the principal queries contained in yours of the 28th instant, and beg leave to refer you to the latter piece in the printed collection of my papers, for farther explanation of the difference between what are called *electrics per se* and *non electrics*. When you have had time to read and consider these papers, I will endeavour to make any new experiments you shall propose, that you think may afford farther light or satisfaction to either of us; and shall be much obliged to you for such remarks, objections, &c. as may occur to you.—I forget whether I wrote you that I have melted brass pins, and steel needles, inverted the poles of the magnetic needle, given a magnetism and polarity to needles

needles that had none, and fired dry gunpowder by the electric ſpark. I have five bottles that contain 8 or 9 gallons each, two of which charg'd, are ſufficient for thoſe purpoſes; but I can charge and diſcharge them all together. There are no bounds (but what expence and labour give) to the force man may raiſe and uſe in the electrical way: For bottle may be added to bottle in infinitum, and all united and diſcharged together as one, the force and effect proportioned to their number and ſize. The greateſt known effects of common lightening, may, I think, without much difficulty be exceeded in this way, which a few years ſince could not have been believed, and even now may ſeem to many a little extravagant to ſuppoſe.—So we are got beyond the ſkill of *Rabelais*'s devils of two years old, who, he humourouſly ſays, had only learnt to thunder and lighten a little round the head of a cabbage.

I am, with ſincere reſpect,

Yotr moſt obliged humble ſervant.

B. FRANKLIN.

Que-

Queries *and* Anſwers, *referr'd to in the foregoing Letter.*

Query, Wherein conſiſts the difference between an *electric* and a *non-electric* body?

Anſwer. The terms electric *per ſe*, and non-electric were firſt uſed to diſtinguiſh bodies, on a miſtaken ſuppoſition that thoſe called electrics *per ſe* alone contained electric matter in their ſubſtance, which was capable of being excited by friction, and of being produced or drawn from them and communicated to thoſe called non-electrics, ſuppoſed to be deſtitute of it: For the glaſs, &c. being rubbed, diſcover'd ſigns of having it, by ſnapping to the finger, attracting, repelling, &c. and could communicate thoſe ſigns to metals and water.—Afterwards it was found, that rubbing of glaſs would not produce the electric matter, unleſs a communication was preſerved between the rubber and the floor; and ſubſequent experiments prov'd that the electric matter was really drawn from thoſe bodies that at firſt were thought to have none in them. Then it was doubted whether glaſs and other bodies called *electrics per ſe* had really any electric matter in them, ſince they apparently afforded none but what they firſt extracted from thoſe which had been called non-electrics. But ſome of my experiments ſhew that glaſs contains it in great quantity, and I now ſuſpect it to be pretty equally diffuſed in all the matter of this terraqueous

O globe

globe. If ſo, the terms *electric per ſe*, and *non electric*, ſhould be laid aſide as improper: And (the only difference being this, that ſome bodies will conduct electric matter, and others will not) the terms *conductors* and *non-conductors* may ſupply their place. If any portion of electric matter is applied to a piece of conducting matter, it penetrates and flows through it, or ſpreads equally on its ſurface; if applied to a piece of non-conducting matter, it will do neither. Perfect conductors of electric matter are only metals and water. Other bodies conducting only as they contain a mixture of thoſe; without more or leſs of which they will not conduct at all.* This (by the way) ſhews a new relation between metals and water heretofore unknown.

To illuſtrate this by a compariſon, which, however, can only give a faint reſemblance. Electric matter paſſes through conductors as water paſſes through a porous ſtone, or ſpreads on their ſurfaces as water ſpreads on a wet ſtone; but when apply'd to non-conductors, 'tis like water dropt on a greaſy ſtone; it neither penetrates, paſſes through, nor ſpreads on the ſurface, but remains in drops where it falls. See farther on this head in my laſt printed piece.

Query. What are the effects of air in electrical experiments.

Anſwer. All I have hitherto obſerved are theſe. Moiſt air

* This propoſition is ſince found to be too general; Mr *Wilſon* having diſcovered that melted wax and roſin will alſo conduct.

air receives and conducts the electrical matter in proportion to its moiſture, quite dry air not all : air is therefore to be claſs'd with the non-conductors. Dry air aſſiſts in confining the electrical atmoſphere to the body it ſurrounds, and prevents its diſſipating : for in vacuo it quits eaſily, and points operate ſtronger, *i. e.* they throw off or attract the electrical matter more freely, and at greater diſtances; ſo that air intervening obſtructs its paſſing from body to body, in ſome degree. A clean electrical phial and wire, containing air inſtead of water, will not be charged nor give a ſhock, any more than if it was fill'd with powder of glaſs ; but exhauſted of air it operates as well as if fill'd with water. Yet, an electrical atmoſphere and air do not ſeem to exclude each other, for we breath freely in ſuch an atmoſphere, and dry air will blow through it without diſplacing or driving it away. I queſtion whether the ſtrongeſt dry N. Weſter would diſſipate it. I once electrified a large cork ball, at the end of a ſilk thread 3 feet long, the other end of which I held in my fingers, and whirl'd it round, like a ſling, 100 times in the air, with the ſwifteſt motion I could poſſibly give it, yet it retained its electrical atmoſphere, though it muſt have paſs'd through 800 yards of air, allowing my arm in giving the motion to add a foot to the ſemi-diameter of the circle.—By quite dry air, I mean the dryeſt we have : for perhaps we never have any perfectly free from moiſture. An electrical atmoſphere raiſed round a thick wire, inſerted in a phial of air, drives out none of the air, nor

on withdrawing that atmofphere will any air rufh in, as I have found by a very curious experiment, accurately made, whence we concluded that the air's elafticity was not affected thereby.

An Experiment towards difcovering more of the Qualities of the Electric Fluid.

FROM the prime conductor, hang a bullet by a wire hook; under the bullet at half an inch diftance, place a bright piece of filver to receive the fparks; then let the wheel be turned, and in a few minutes (if the repeated fparks continually ftrike in the fame fpot) the filver will receive a blue ftain near the colour of a watch ftring.

A bright piece of iron will alfo be fpotted, but not with that colour; it rather feems corroded.

On gold, brafs, or tin, I have not perceived that it makes any impreffion. But the fpots on the filver or iron will be the fame, whether the bullet be lead, brafs, gold, or filver.

On a filver bullet, there will alfo appear a fmall fpot, as well as on the plate below it.

LET-

LETTER VII.

FROM

Mr E. KINNERSLEY, at *Boſton*,

TO

BENJAMIN FRANKLIN, Eſq; at *Philadelphia*.

SIR *Feb.* 3, 1752.

I Have the following experiments to communicate: I held in one hand a wire, which was faſten'd at the other end to the handle of a pump, in order to try whether the ſtroke from the prime conductor, through my arms, would be any greater, than when convey'd only to the ſurface of the earth, but could diſcover no difference.

I placed the needle of a compaſs on the point of a long pin, and holding it in the atmoſphere of the prime conductor, at the diſtance of about three inches, found it to whirl round, like the flyers of a jack, with great rapidity.

I ſuſpended with ſilk, a cork ball, about the bigneſs of a pea, and preſented to it, rubbed amber, ſealing wax, and ſulphur, by each of which it was ſtrongly repelled; then

then I tried rubbed glaſs and china, and found that each of theſe would attract it, until it became electrified again, and then it would be repelled as at firſt; and while thus repelled by the rubbed glaſs or china, either of the others when rubbed would attract it. Then I electrified the ball, with the wire of a charged phial, and preſented to it rubbed glaſs (the ſtopper of a decanter) and a china tea cup, by which it was as ſtrongly repelled, as by the wire; but when I preſented either of the other rubbed electrics, it would be ſtrongly attracted, and when I electrified it, by either of theſe, till it became repelled, it would be attracted by the wire of the phial, but be repelled by its coating.

Theſe experiments ſurprized me very much, and have induced me to infer the following parodoxes.

1. If a glaſs globe be placed at one end of a prime conductor, and a ſulphur one at the other end, both being equally in good order, and in equal motion, not a ſpark of fire can be obtain'd from the conductor; but one globe will draw out, as faſt as the other gives in.

2. If a phial be ſuſpended on the conductor, with a chain from its coating to the table, and only one of the globes be made uſe of at a time, 20 turns of the wheel, for inſtance, will charge it; after which, ſo many turns of the other wheel will diſcharge it; and as many more will charge it again.

3. The globes being both in motion, each having a ſeparate conductor, with a phial ſuſpended on one of them,

and

and the chain of it faſtened to the other, the phial will become charged; one globe charging poſitively, the other negatively.

4. The phial being thus charged, hang it in like manner on the other conductor; ſet both wheels a going again, and the ſame number of turns that charged it before, will now diſcharge it; and the ſame number repeated, will charge it again.

5. When each globe communicates with the ſame prime conductor, having a chain hanging from it to the table, one of them, when in motion, (but which I can't ſay) will draw fire up through the cuſhion, and diſcharge it through the chain; the other will draw it up through the chain, and diſcharge it through the cuſhion.

I ſhould be glad if you would ſend to my houſe for my ſulphur globe, and the cuſhion belonging to it, and make the trial; but muſt caution you not to uſe chalk on the cuſhion, ſome fine powdered ſulphur will do better. If, as I expect, you ſhould find the globes to charge the prime conductor differently, I hope you will be able to diſcover ſome method of determining which it is that charges poſitively.

I am, &c.

E. KINNERSLEY.

LETTER VIII.

FROM

BENJAMIN FRANKLIN, *Esq*; of *Philadelphia*,

TO

Mr E. KINNERSLEY, at *Boston*.

SIR, *March* 2, 1752.

I Thank you for the experiments communicated. I sent immediately for your brimstone globe, in order to make the trials you desired, but found it wanted centers, which I have not time now to supply; but the first leisure I will get it fitted for use, try the experiments, and acquaint you with the result.

In the mean time I suspect, that the different attractions and repulsions you observed, proceeded rather from the greater or smaller quantities of the fire you obtained from different bodies, than from its being of a different *kind*, or having a different *direction*. In haste,

I am, &c.

B. FRANKLIN.

LET-

LETTER IX.

FROM

BENJAMIN FRANKLIN, *Esq*; of PHILADELPHIA.

TO

To Mr E. KINNERSLEY, at *Boston*.

SIR, *March* 16, 1752.

HAving brought your brimstone globe to work, I try'd one of the experiments you proposed, and was agreeably surprized to find, that the glass globe being at one end of the conductor, and the sulphur globe at the other end, both globes in motion, no spark could be obtained from the conductor, unless when one globe turned slower, or was not in so good order as the other; and then the spark was only in proportion to the difference, so that turning equally, or turning that slowest which work'd best, would again bring the conductor to afford no spark.

I found also, that the wire of a phial charg'd by the glass globe, attracted a cork ball that had touch'd the wire of a phial charged by the brimstone globe, and *vice versa*,

ſo that the cork continued to play between the two phials, juſt as when one phial was charged through the wire, the other through the coating, by the glaſs globe alone. And two phials charged, the one by the brimſtone globe, the other by the glaſs globe, would be both diſcharged by bringing their wires together, and ſhock the perſon holding the phials.

From theſe experiments, one may be certain that your 2d, 3d, and 4th propoſed experiments, would ſucceed exactly as you ſuppoſe, though I have not tried them, wanting time.—I imagine it is the glaſs globe that charges poſitively, and the ſulphur negatively, for theſe reaſons, 1. Though the ſulphur globe ſeems to work equally well with the glaſs one, yet it can never occaſion ſo large and diſtant a ſpark between my knuckle and the conductor when the ſulphur one is working, as when the glaſs one is uſed; which, I ſuppoſe, is occaſioned by this, that bodies of a certain bigneſs cannot ſo eaſily part with a quantity of electrical fluid they have and hold attracted *within* their ſubſtance, as they can receive an additional quantity *upon* their ſurface by way of atmoſphere. Therefore ſo much cannot be drawn *out* of the conductor, as can be thrown *on* it. 2. I obſerve that the ſtream or bruſh of fire appearing at the end of a wire connected with the conductor, is long, large, and much diverging, when the glaſs globe is uſed, and makes a ſnapping (or rattling) noiſe: but when the ſulphur one is uſed, it is ſhort, ſmall, and makes a hiſſing noiſe; and juſt the re-

verſe

verſe of both happens, when you hold the ſame wire in your hand, and the globes are worked alternately: the bruſh is large, long, diverging and ſnapping (or rattling) when the ſulphur globe is turn'd; ſhort, ſmall, and hiſſing when the glaſs globe is turn'd.---When the bruſh is long, large, and much diverging, the body to which it joins, ſeems to me to be throwing the fire out; and when the contrary appears, it ſeems to be drinking in. 3. I obſerve, that when I held my nuckle before the ſulphur globe, while turning, the ſtream of fire between my knuckle and the globe, ſeems to ſpread on its ſurface, as if it flowed from the finger; on the glaſs globe 'tis otherwiſe. 4. The cool wind (or what was called ſo) that we uſed to feel as coming from an electrified point, is much more ſenſible, when the glaſs globe is uſed, than when the ſulphur one.---But theſe are haſty thoughts. As to your fifth paradox, it muſt likewiſe be true, if the globes are alternately worked; but if work'd together, the fire will neither come up nor go down by the chain, becauſe one globe will drink it as faſt as the other produces it.

I ſhould be glad to know whether the effects would be contrary, if the glaſs globe is ſolid, and the ſulphur globe is hollow; but I have no means at preſent of trying.

In your journeys, your glaſs globes meet with accidents, and ſulphur ones are heavy and inconvenient. *Query.* Would not a thin plane of brimſtone, caſt on a board, ſerve on occaſion as a cuſhion, while a globe of leather ſtuffed

ſtuffed (properly mounted) might receive the fire from the ſulphur, and charge the conductor poſitively? Such a globe would be in no danger in breaking. I think I can conceive how it may be done; but have not time to add more than that I am,

Yours, &c.

B. FRANKLIN.

LETTER X.

FROM

BENJAMIN FRANKLIN, *Eſq*; of *Philadelphia.*

Oct. 19, 1752.

AS frequent mention is made in the news papers from *Europe*, of the ſucceſs of the *Philadelphia* experiment for drawing the electric fire from clouds by means of pointed rods of iron erected on high buildings, *&c.* it may be agreeable to inform the curious that the ſame experiment has ſucceeded in *Philadelphia*, though made in a different and more eaſy manner, which is as follows:

Make a ſmall croſs of two light ſtrips of cedar, the arms

arms ſo long as to reach to the four corners of a large thin ſilk handkerchief when extended; tie the corners of the handkerchief to the extremities of the croſs, ſo you have the body of a kite; which being properly accommodated with a tail, loop, and ſtring, will riſe in the air, like thoſe made of paper; but this being of ſilk, is fitter to bear the wind and wet of a thunder guſt without tearing. To the top of the upright ſtick of the croſs is to be fixed a very ſharp pointed wire, riſing a foot or more above the wood. To the end of the twine, next the hand, is to be ty'd a ſilk ribbon, and where the ſilk and twine join, a key may be faſtened. This kite is to be raiſed when a thunder guſt appears to be coming on, and the perſon who holds the ſtring muſt ſtand within a door, or window, or under ſome cover, ſo that the ſilk ribbon may not be wet; and care muſt be taken that the twine does not touch the frame of the door or window. As ſoon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine, will be electrified, and the looſe filaments of the twine will ſtand out every way, and be attracted by an approaching finger. And when the rain has wet the kite and twine, ſo that it can conduct the electric fire freely, you will find it ſtream out plentifully from the key on the approach of your knuckle. At this key the phial may be charged; and from electric fire thus obtained, ſpirits may be kindled, and all the other electric experiments be performed, which are uſually done by the

help

help of a rubbed glaſs globe or tube; and thereby the ſameneſs of the electric matter with that of lightening completely demonſtrated.

B. F.

LETTER XI.

FROM

BENJAMIN FRANKLIN, *Eſq*; of *Philadelphia*,

AS you tell me our friend *Cave* is about to add ſome later experiments to my pamphlet, with the *Errata*, I ſend a copy of a letter from Dr *Colden*, which may help to fill a few pages; alſo my kite experiment in the *Penſylvania Gazette*: to which I have nothing new to add, except the following experiment towards diſcovering more of the qualities of the electric fluid. From the prime conductor, hang a bullet by a wire hook; under the bullet, at half an inch diſtance, place a bright piece of ſilver to receive the ſparks; then let the wheel be turned, and in a few minutes, (if the repeated ſparks continually ſtrike in the ſame ſpot) the ſilver will receive a blue ſtain near the colour of a watch ſpring. A bright piece of iron will alſo be ſpotted, but

not

not with that colour: it rather ſeems to be corroded. On gold, braſs, or tin, I have not perceived that it makes any impreſſion. But the ſpots on the ſilver or iron will be the ſame, whether the bullet be lead, braſs, gold, or ſilver. On a ſilver bullet there will alſo appear a ſmall ſpot, as well as in the plate below it.

F *I N I S.*

ADDITIONAL ERRATA *in* PART I. *to the printed* ELECTRICAL PAPERS. *By* B. FRANKLIN.

PAGE 38, line 2. read *reprefented by* A and B, *Fig*. 6.

Page 40, line 7. r. *repulfion.*

Page 65, l. 19. r. *Aqua Regia.*

Page 70, l. 6. r. *rubbed.*

Fig. VI. in the plate, wants the referring letters A, B, C, D. In the copy that Fig. was mentioned as a profile of a piece of water, the little circles reprefenting particles. The two upper circles were mark'd A and B, and two others in the under line or row C and D. As it ftands 'tis wholly unintelligible.

Page 73, l. 17. r. *air.*

Page 74, l. 7. r. *electrical.*

Page 81, l. 3. place a *comma* at conduct, and dele *comma* at floor.

Page 85, l. 5. r. *difcharged.* l. 13, r. *p.* 24.

Page 86, l. 20. r. *after one.*

NEW EXPERIMENTS
AND
OBSERVATIONS
ON
ELECTRICITY.
MADE AT
Philadelphia in *America*.

BY
BENJAMIN FRANKLIN, *Esq*;

Communicated to P. COLLINSON, *Esq*; of *London*, F.R.S.

And read at the Royal Society *June* 27, and *July* 4, 1754.

To which are added

A Paper on the same Subject by *J. Canton*, M.A. F.R.S. and read at the Royal Society *Dec.* 6, 1753; and another in defence of Mr *Franklin* against the Abbe *Nollet*, by Mr *D. Colden*, of *New York*.

PART III.

LONDON:

Printed and sold by D. HENRY, and R. CAVE, at *St John's-Gate*. 1754. (Price 1 *s*.)

LETTER XII.

FROM

BENJ. FRANKLIN, *Esq*; of *Philadelphia*.

TO

PETER COLLINSON, *Esq*; F. R. S. *London*.

SIR, *Philadelphia*, *September* 1753.

IN my former paper on this ſubject, wrote firſt in 1747, enlarged and ſent to *England* in 1749, I conſidered the ſea as the grand ſource of lightning; imagining its luminous appearance to be owing to electric fire, produc'd by friction between the particles of water and thoſe of ſalt. Living far from the ſea, I had then no opportunity of making experiments on the ſea water, and ſo embrac'd this opinion too haſtily.

For in 1750 and 1751, being occaſionally on the ſea coaſt, I found, by experiments, that ſea water in a bottle, tho' at firſt it would by agitation appear luminous, yet in a few hours it loſt that virtue; *hence, and from this*, that I could not by agitating a ſolution of ſea ſalt in water pro-

duce any light, I firſt began to doubt of my former hypotheſis, and to ſuſpect that the luminous appearance in ſea water muſt be owing to ſome other principles.

I then conſidered whether it were not poſſible, that the particles of air, being electrics *per ſe*, might, in hard gales of wind, by their friction againſt trees, hills, buildings, *&c.* as ſo many minute electric globes, rubbing againſt non-electric cuſhions, draw the electric fire from the earth; and that the riſing vapours might receive that fire from the air, and by ſuch means the clouds become electrified.

If this were ſo, I imagined that by forcing a conſtant violent ſtream of air againſt my prime conductor, by bellows, I ſhould electrify it *negatively*; the rubbing particles of air, drawing from it part of its natural quantity of the electric fluid. I accordingly made the experiment, but it did not ſucceed.

In *September* 1752, I erected an iron rod to draw the lightning down into my houſe, in order to make ſome experiments on it, with two bells to give notice when the rod ſhould be electrify'd: A contrivance obvious to every electrician.

I found the bells rang ſometimes when there was no lightning or thunder, but only a dark cloud over the rod; that ſometimes after a flaſh of lightning they would ſuddenly ſtop; and at other times, when they had not rang before, they would, after a flaſh, ſuddenly begin to ring; that the electricity was ſometimes very faint, ſo that when

a ſmall

a ſmall ſpark was obtain'd, another could not be got for ſometime after; at other times the ſparks would follow extremely quick, and once I had a continual ſtream from bell to bell, the ſize of a crow-quill: Even during the ſame guſt there were conſiderable variations.

In the winter following I conceived an experiment, to try whether the clouds were electrify'd *poſitively*, or *negatively*; but my pointed rod, with its apparatus, becoming out of order, I did not refit it till towards the ſpring, when I expected the warm weather would bring on more frequent thunder-clouds.

The experiment was this: To take two phials; charge one of them with lightning from the iron rod, and give the other an equal charge by the electric glaſs globe, thro' the prime conductor: When charg'd, to place them on a table within three or four inches of each other, a ſmall cork ball being ſuſpended by a fine ſilk thread from the ceiling, ſo as it might play between the wires. If both bottles then were electrifyed *poſitively*, the ball being attracted and repell'd by one, muſt be alſo repell'd by the other. If the one *poſitively*, and the other *negatively*; then the ball would be attracted and repell'd alternately by each, and continue to play between them as long as any conſiderable charge remained.

Being very intent on making this experiment, it was no ſmall mortification to me, that I happened to be abroad during two of the greateſt thunder-ſtorms we had early in the ſpring; and tho' I had given orders in my family, that

if the bells rang when I was from home, they ſhould catch ſome of the lightning for me in electrical phials, and they did ſo; yet it was moſtly diſſipated before my return; and in ſome of the other guſts, the quantity of lightning I was able to obtain, was ſo ſmall, and the charge ſo weak, that I could not ſatisfy myſelf: Yet I ſometimes ſaw what heighten'd my ſuſpicious and inflam'd my curioſity.

At laſt, on the 12th of *April* 1753, there being a ſmart guſt of ſome continuance, I charg'd one phial pretty well with lightning, and the other equally, as near as I could judge, with electricity from my glaſs globe; and having plac'd them properly, I beheld, with great ſurprize and pleaſure, the cork ball play briſkly between them; and was convinc'd that one bottle was electriſed *negatively*.

I repeated this experiment ſeveral times during the guſt, and in eight ſucceeding guſts, always with the ſame ſucceſs; and being of opinion (for reaſons I formerly gave in my letter to Mr *Kinnerſley*, ſince printed in *London*) that the glaſs globe electriſes *poſitively*; I concluded that the clouds are *always* electriſed *negatively*, or have always in them leſs than their natural quantity of the electric fluid.

Yet notwithſtanding ſo many experiments, it ſeems I concluded too ſoon; for at laſt, *June* the 6th, in a guſt which continued from five o'clock, P. M. to 7, I met with one cloud that was electriſed poſitively, tho' ſeveral that paſs'd over my rod before, during the ſame guſt, were in the negative ſtate. This was thus diſcovered:

I had

I had another concurring experiment, which I often repeated, to prove the negative ſtate of the clouds, *viz.* While the bells were ringing, I took the phial charg'd from the glaſs globe, and apply'd its wire to the erected rod; conſidering, that if the clouds were electrified *poſitively*, the rod, which received its electricity from them, muſt be ſo too; and then the additional *poſitive* electricity of the phial would make the bells ring faſter:—But, if the clouds were in a *negative* ſtate, they muſt exhauſt the electric fluid from my rod, and bring that into the ſame negative ſtate with themſelves; and then the wire of a poſitively charg'd phial, ſupplying the rod with what it wanted (which it was oblig'd otherwiſe to draw from the earth by means of the pendulous braſs ball playing between the two bells) the ringing would ceaſe till the bottle was diſcharg'd.

In this manner I quite diſcharged into the rod ſeveral phials that were charged from the glaſs globe, the electric fluid ſtreaming from the wire to the rod, 'till the wire would receive no ſpark from the finger; and during this ſupply to the rod from the phial, the bells ſtopt ringing; but by continuing the application of the phial wire to the rod, I exhauſted the natural quantity from the inſide ſurface of the ſame phials, or, as I call it, charg'd them *negatively*.

At length, while I was charging a phial by my glaſs globe, to repeat this experiment, my bells, of themſelves, ſtopt ringing, and, after ſome pauſe, began to ring again. —But now, when I approached the wire of the charg'd

phial to the rod, inſtead of the uſual ſtream that I expec~~ted from~~ the wire to the rod, there was no ſpark; not even when I brought the wire and the rod to touch; yet the bells continued ringing vigorouſly; which prov'd to me, that the rod was then *poſitively* electrify'd, as well as the wire of the phial, and equally ſo; and conſequently, that the particular cloud then over the rod, was in the ſame poſitive ſtate. This was near the end of the guſt.

But this was a ſingle experiment, which however deſtroys my firſt too general concluſion, and reduces me to this: *That the clouds of a thunder-guſt are moſt commonly in a negative ſtate of electricity, but ſometimes in a poſitive ſtate.*

The latter I believe is rare; for tho' I ſoon after the laſt experiment, ſet out on a journey to *Boſton*, and was from home moſt part of the ſummer, which prevented my making farther trials and obſervations; yet Mr *Kinnerſley* returning from the iſlands juſt as I left home, purſu'd the experiments during my abſence, and informs me that he always found the clouds in the *negative* ſtate.

So that, for the moſt part, in thunder-ſtrokes, *'tis the earth that ſtrikes into the clouds, and not the clouds that ſtrike into the earth.*

Thoſe who are vers'd in electric experiments, will eaſily conceive, that the effects and appearances muſt be nearly the ſame in either caſe; the ſame exploſion, and the ſame flaſh between one cloud and another, and between the

clouds

clouds and mountains, &c. the ſame rending of trees, walls, &c. which the electric fluid meets with in its paſſage, and the ſame fatal ſhock to animal bodies; and that pointed rods fix'd on buildings, or maſts of ſhips, and communicating with the earth or ſea, muſt be of the ſame ſervice in reſtoring the equilibrium ſilently between the earth and clouds, or in conducting a flaſh or ſtroke, if one ſhould be, ſo as to ſave harmleſs the houſe or veſſel: For points have equal power to throw off, as to draw on the electric fire, and rods will conduct up as well as down.

But tho' the light gain'd from theſe experiments makes no altration in the practice, it makes a conſiderable one in the theory. And now we as much need an hypotheſis to explain by what means the clouds become negatively, as before to ſhew how they became poſitively electrified.

I cannot forbear venturing ſome few conjectures on this occaſion: They are what occur to me at preſent; and tho' future diſcoveries ſhould prove them not wholly right, yet they may in the mean time be of ſome uſe, by ſtirring up the curious to make more experiments, and occaſion more exact diſquiſitions.

I conceive then, that this globe of earth and water, with its plants, animals and buildings, have, diffus'd throughout their ſubſtance, a quantity of the electric fluid, juſt as much as they can contain, which I call the *natural quantity*.

That this natural quantity is not the ſame in all kinds of common matter under the ſame dimenſions, nor in the

ſame

ſame kind of common matter in all circumſtances; but a ſolid foot, for inſtance, of one kind of common matter, may contain more of the electric fluid than a ſolid foot of ſome other kind of common matter; and a pound weight of the ſame kind of common matter may, when in a rarer ſtate, contain more of the electric fluid than when in a denſer ſtate.

For the electric fluid, being attracted by any portion of common matter, the parts of that fluid (which have among themſelves a mutual repulſion) are brought ſo near to each other by the attraction of the common matter that abſorbs them, as that their repulſion is equal to the condenſing power of attraction in common matter; and then ſuch portion of common matter will abſorb no more.

Bodies of different kinds having thus attracted and abſorb'd what I call their *natural quantity*, *i. e.* juſt as much of the electric fluid as is ſuited to their circumſtances of denſity, rarity, and power of attracting, do not then ſhow any ſigns of electricity among each other.

And if more electric fluid be added to one of theſe bodies, it does not enter, but ſpreads on the ſurface, forming an atmoſphere; and then ſuch body ſhows ſigns of electricity.

I have in a former paper compar'd common matter to a ſponge, and the electric fluid to water: I beg leave once more to make uſe of the ſame compariſon, to illuſtrate farther my meaning in this particular.

When

When a ſponge is ſomewhat condens'd by being ſqueez-ed between the fingers, it will not receive and retain ſo much water as when in its more looſe and open ſtate.

If *more* ſqueez'd and condens'd, ſome of the water will come out of its inner parts, and flow on the ſurface.

If the preſſure of the fingers be intirely removed, the ſponge will not only reſume what was lately forced out, but attract an additional quantity.

As the ſponge in its rarer ſtate will *naturally* attract and abſorb *more* water, and in its denſer ſtate will *naturally* attract and abſorb *leſs* water; we may call the quantity it attracts and abſorbs in either ſtate, its *natural quantity*, the ſtate being conſidered.

Now what the ſponge is to water, the ſame is water to the electric fluid.

When a portion of water is in its common denſe ſtate, it can hold no more electric fluid than it has; if any be added, it ſpreads on the ſurface.

When the ſame portion of water is rarify'd into vapour, and forms a cloud, it is then capable of receiving and abſorbing a much greater quantity; there is room for each particle to have an electric atmoſphere.

Thus water, in its rarify'd ſtate, or in the form of a cloud, will be in a negative ſtate of electricity; it will have leſs than its *natural quantity*; that is, leſs than it is naturally capable of attracting and abſorbing in that ſtate.

Such a cloud, then, coming ſo near the earth as to be within the ſtriking diſtance, will receive from the earth a

flaſh of the electric fluid; which flaſh, to ſupply a great extent of cloud, muſt ſometimes contain a very great quantity of that fluid.

Or ſuch a cloud, paſſing over woods of tall trees, may from the points and ſharp edges of their moiſt top leaves, receive ſilently ſome ſupply.

A cloud being by any means ſupply'd from the earth, may ſtrike into other clouds that have not been ſupply'd, or not ſo much ſupply'd; and thoſe to others, till an equilibrium is produc'd among all the clouds that are within ſtriking diſtance of each other.

The cloud thus ſupply'd, having parted with much of what it firſt receiv'd, may require and receive a freſh ſupply from the earth, or from ſome other cloud, which by the wind is brought into ſuch a ſituation as to receive it more readily from the earth.

Hence repeated, and continual ſtrokes and flaſhes till the clouds have all got nearly their natural quantity as clouds; or till they have deſcended in ſhowers, and are united again with this terraqueous globe, their original.

Thus thunder-clouds are generally in a negative ſtate of electricity compar'd with the earth, agreeable to moſt of our experiments; yet as by one experiment we found a cloud electris'd poſitively; I conjecture that, in that caſe, ſuch cloud, after having received what was, in its rare ſtate, only its *natural quantity*, became compreſs'd by the driving winds, or ſome other means, ſo that part of what it had abſorb'd was forc'd out, and form'd an electric at-

moſphere

moſphere around it in its denſer ſtate. Hence it was capable of communicating poſitive electricity to my rod.

To ſhow that a body in different circumſtances of dilatation and contraction is capable of receiving and retaining more or leſs of the electric fluid on its ſurface, I would relate the following experiment. I placed a clean wine glaſs on the floor, and on it a ſmall ſilver can. In the can I put about three yards of braſs chain; to one end of which I faſtened a ſilk thread, which went right up to the cieling, where it paſſed over a pulley, and came down again to my hand, that I might at pleaſure draw the chain up out of the can, extending it till within a foot of the cieling, and let it gradually ſink into the can again.——From the cieling, by another thread of fine raw ſilk, I ſuſpended a ſmall light lock of cotton, ſo as that when it hung perpendicularly, it came in contact with the ſide of the can.——Then approaching the wire of a charged vial to the can, I gave it a ſpark, which flow'd round it in an electric atmoſphere; and the lock of cotton was repelled from the ſide of the can to the diſtance of about nine or ten inches. The can would not then receive another ſpark from the wire of the vial; but as I gradually drew up the chain, the atmoſphere of the can diminiſh'd by flowing over the riſing chain, and the lock of cotton accordingly drew nearer and nearer to the can; and then, if I again brought the vial wire near the can, it wonld receive another ſpark, and the cotton fly off again to its firſt diſtance; and thus, as the chain

was drawn higher, the can would receive more ſparks; becauſe the can and extended chain were capable of ſupporting a greater atmoſphere than the can with the chain gather'd up into its belly.——And that the atmoſphere round the can was diminiſhed by raiſing the chain, and increaſed again by lowering it, is not only agreeable to reaſon, ſince the atmoſphere of the chain muſt be drawn from that of the can, when it roſe, and returned to it again when it fell; but was alſo evident to the eye, the lock of cotton always approaching the can when the chain was drawn up, and receding when it was let down again.

Thus we ſee that increaſe of ſurface makes a body capable of receiving a greater electric atmoſphere: But this experiment does not, I own, fully demonſtrate my new hypotheſis; for the braſs and ſilver ſtill continue in their ſolid ſtate, and are not rarified into vapour, as the water is in clouds. Perhaps ſome future experiments on vapourized water may ſet this matter in a clearer light.

One ſeemingly material objection ariſes to the new hypotheſis, and it is this. If water, in its rarified ſtate, as a cloud, requires, and will abſorb more of the electric fluid than when in its denſe ſtate as water, why does it not acquire from the earth all it wants at the inſtant of its leaving the ſurface, while it is yet near, and but juſt riſing in vapour? To this difficulty I own I cannot at preſent give a ſolution ſatisfactory to myſelf: I thought, how-

however, that I ought to ſtate it in its full force, as I have done, and ſubmit the whole to examination.

And I would beg leave to recommend it to the curious in this branch of natural philoſophy, to repeat with care and accurate obſervation, the experiments I have reported in this and former papers relating to *poſitive* and *negative* electricity, with ſuch other relative ones as ſhall occur to to them, that it may be certainly known whether the electricity communicated by a glaſs globe, be *really poſitive.* And alſo I would requeſt all who may have an opportunity of obſerving the recent effects of lightning on buildings, trees, *&c.* that they would conſider them particularly with a view to diſcover the direction. But in theſe examinations, this one thing is always to be underſtood, *viz.* that a ſtream of the electric fluid paſſing thro' wood, brick, metal, *&c.* while ſuch fluid paſſes in *ſmall quantity*, the mutually repulſive power of its parts is confined and overcome by the coheſion of the parts of the body it paſſes through, ſo as to prevent an exploſion; but when the fluid comes in a quantity too great to be confin'd by ſuch coheſion, it explodes, and rends or fuſes the body that endeavour'd to confine it. If it be wood, brick, ſtone, or the like, the ſplinters will flie off on that ſide where there is leaſt reſiſtance. And thus, when a whole is ſtruck thro' paſte-board by the electrify'd jar, if the ſurfaces of the paſte-board are not confin'd or compreſs'd, there will be a bur rais'd all round the hole on both ſides the paſteboard; but if one ſide be confin'd, ſo that the bur cannot be rais'd on that ſide,

ſide, it will be all rais'd on the other, which way ſoever the fluid was directed. For the bur round the outſide of the hole, is the effect of the exploſion every way from the center of the ſtream, and not an effect of the direction.

In every ſtroke of lightning, I am of opinion that the ſtream of the electric fluid, moving to reſtore the equilibrium between the cloud and the earth, does always previouſly find its paſſage, and mark out, as I may ſay, its own courſe, taking in its way all the conductors it can find; ſuch as metals, damp walls, moiſt wood, *&c.* and will go conſiderably out of a direct courſe, for the ſake of the aſſiſtance of good conductors; and that, in this courſe, it is actually moving, tho' ſilently and imperceptibly, before the exploſion, in and among the conductors; which exploſion happens only when the conductors cannot diſcharge it as faſt as they receive it, by reaſon of their being incompleat, diſunited, too ſmall, or not of the beſt materials for conducting. Metalline rods, therefore, of ſufficient thickneſs, and extending from the higheſt part of an edifice to the ground, being of the beſt materials and compleat conductors, will, I think, ſecure the building from damage; either by reſtoring the equilibrium ſo faſt as to prevent a ſtroke, or by conducting it in the ſubſtance of the rod as far as the rod goes, ſo that there ſhall be no exploſion but what is above its point, between that and the clouds.

If it be aſk'd, what thickneſs of a metalline rod may be ſuppos'd ſufficient? In anſwer, I would remark, that five large glaſs jars, ſuch as I have deſcribed in my former pa-

pers,

pers, difcharge a very great quantity of electricy, which neverthelefs will be all conducted round the corner of a book, by the fine filleting of gold on the cover, it following the gold the fartheft way about, rather than take the fhorter courfe through the cover, that not being fo good a conductor. Now in this line of gold the metal is fo extremely thin as to be little more than the colour of gold, and on an octavo book is not in the whole an inch fquare, and therefore not the 36th part of a grain according to M. *Reaumur*; yet 'tis fufficient to conduct the charge of 5 large jars, and how many more I know not. Now, I fuppofe a wire of $\frac{1}{4}$ inch diameter to contain about 5000 times as much metal as there is in that gold line, and if fo, it will conduct the charge of 25,000 fuch glafs jarrs, which is a quantity, I imagine, far beyond what was ever contain'd in any one ftroke of natural lightning. But arod of half an inch diameter would conduct four times as much as one of a quarter.

And with regard to conducting; tho' a certain thicknefs of metal be required to conduct a great quantity of electricity, and, at the fame time, keep its own fubftance firm and unfeparated; and a lefs quantity, as a very fmall wire for inftance, will be deftroy'd by the explofion; yet fuch fmall wire will have anfwer'd the end of conducting that ftroke, tho' it become incapable of conducting another. And confidering the extream rapidity with which the electric fluid moves without exploding, when it has a free paffage, or compleat metal communication, I fhould think

think a vaſt quantity would be conducted in a ſhort time, either to or from a cloud, to reſtore its equilibrium with the earth, by means of a very ſmall wire; and therefore thick rods ſhould ſeem not ſo neceſſary.—However, as the quantity of lightning diſcharg'd in one ſtroke cannot well be meaſured, and, in different ſtrokes, is certainly very various, in ſome much greater than others; and as iron (the beſt metal for the purpoſe, being leaſt apt to fuſe) is cheap, it may be well enough to provide a larger canal to guide that impetuous blaſt, than we imagine neceſſary: For, though one middling wire may be ſufficient, two or three can do no harm. And time, with careful obſervations well compar'd, will at length point out the proper ſize to greater certainty.

Pointed rods erected on edifices may likewiſe often prevent a ſtroke, in the following manner. An eye ſo ſituated as to view horizontally the under ſide of a thunder cloud, will ſee it very ragged, with a number of ſeparate fragments, or petty clouds, one under another, the loweſt ſometimes not far from the earth. Theſe, as ſo many ſtepping-ſtones, aſſiſt in conducting a ſtroke between the cloud and a building. To repreſent theſe by an experiment, take two or three locks of fine looſe cotton, connect one of them with the prime conductor by a fine thread of two inches, (which may be ſpun out of the ſame lock by the fingers) another to that, and the third to the ſecond, by like threads.—Turn the globe, and you

will

will ſee theſe locks extend themſelves towards the table, (as the lower ſmall clouds do towards the earth) being attracted by it: But on preſenting a ſharp point erect under the loweſt, it will ſhrink up to the ſecond, the ſecond to the firſt, and all together to the prime conductor, where they will continue as long as the point continues under them. May not, in like manner, the ſmall electrified clouds, whoſe equilibrium with the earth is ſoon reſtor'd by the point, riſe up to the main body, and by that means occaſion ſo large a vacancy, as that the grand cloud cannot ſtrike in that place?

Theſe thoughts, my dear friend, are many of them crude and haſty; and if I were merely ambitious of acquiring ſome reputation in philoſophy, I ought to keep them by me, till corrected and improved by time and farther experience. But ſince even ſhort hints, and imperfect experiments in any new branch of ſcience, being communicated, have oftentimes a good effect, in exciting the attention of the ingenious to the ſubject, and ſo become the occaſion of more exact diſquiſitions, and more compleat diſcoveries. You are at liberty to communicate this paper to whom you pleaſe; it being of more importance that knowledge ſhould increaſe, than that your friend ſhould be thought an accurate philoſopher.

LETTER XIII.

FROM

BENJAMIN FRANKLIN, *Eſq*; at *Philadelphia.*

TO

PETER COLLINSON, *Eſq*; F. R. S. *at London.*

SIR, *April* 18, 1754.

SINCE *September* laſt, having been abroad on two long journeys, and otherwiſe much engag'd, I have made but few obſervations on the *poſitive* and *negative* ſtate of electricity in the clouds. But Mr *Kinnerſley* kept his rod and bells in good order, and has made many.

Once this winter the bells rang a long time, during a fall of ſnow, tho' no thunder was heard or lightning ſeen. Sometimes the flaſhes and cracks of the electric matter between bell and bell were ſo large and loud, as to be heard all over the houſe: but by all his obſervations, the clouds were conſtantly in a negative ſtate, till about ſix weeks ago, when he found them once to change in a few minutes from the negative to the poſitive. About a fortnight

night after that he made another obſervation of the ſame kind; and laſt *Monday* afternoon, the wind blowing hard at S. E. and veering round to N. E. with many thick driving clouds, there were five or ſix ſucceſſive changes from negative to poſitive, and from poſitive to negative, the bells ſtopping a minute or two between every change. Beſides the methods mentioned in my paper of *September* laſt, of diſcovering the electrical ſtate of the clouds, the following may be us'd. When your bells are ringing, paſs a rubb'd tube by the edge of the bell, connected with your pointed rod: if the cloud is then in a negative ſtate, the ringing will ſtop; if in a poſitive ſtate, it will continue, and perhaps be quicker. Or, ſuſpend a very ſmall cork-ball by a fine ſilk thread, ſo that it may hang cloſe to the edge of the rod-bell: then whenever the bell is electrified, whether poſitively or negatively, the little ball will be repell'd, and continue at ſome diſtance from the bell. Have ready a round-headed glaſs ſtopper of a decanter, rub it on your ſide 'till it is electrified, then preſent it to the cork-ball. If the electricity in the ball is poſitive, it will be repell'd from the glaſs ſtopper as well as from the bell. If negative, it will fly to the ſtopper.

REMARKS
On the Abbe NOLLET's
LETTERS on ELECTRICITY.
TO
BENJ. FRANKLIN, *Esq*; of *Philadelphia*.
BY
Mr DAVID COLDEN, of *New-York*,

SIR, *Coldenham*, in *N. York*, *Dec.* 4, 1753.

IN considering the Abbé *Nollet*'s letters to Mr *Franklin*, I am obliged to paſs by all the experiments which are made with, or in, bottles hermetically ſealed, or exhauſted of air; becauſe, not being able to repeat the experiments, I could not ſecond any thing, which occurs to me thereon, by experimental proof. Wherefore, the firſt point wherein I can dare to give my opinion, is in the Abbe's 4th letter, *p.* 66, where he undertakes to prove, that the electric matter paſſes from one ſurface to another through the intire thickneſs of the glaſs: He takes Mr *Franklin*'s experiment of the magical picture, and writes thus of it. " When you electriſe a pane of glaſs coated

on

"on both ſides with metal, it is evident that whatever is "placed on the ſide oppoſite to that which receives the "electricity from the conductor, receives alſo an evident "electrical virtue." Which Mr *Franklin* ſays, is that equal quantity of electric matter, driven out of this ſide, by what is received from the conductor on the other ſide; and which will continue to give an electrical virtue, to any thing in contact with it, till it is entirely diſcharged of its electrical fire. To which the Abbé thus objects: "Tell me, ſays he, I pray you, how much time is neceſſary for this pretended diſcharge? I can aſſure you, "that after having maintain'd the electriſation for hours, "this ſurface, which ought, as it ſeems to me, to be entirely diſcharged of its electrical matter, conſidering either the vaſt number of ſparks that were drawn from it, "or the time that this matter had been expoſed to the action "of the expulſive cauſe; this ſurface, I ſay, appeared rather better electriſed thereby, and more proper to produce all the effects of an actual electric body." *p.* 68.

The Abbé does not tell us what thoſe effects were: all the effects I could never obſerve, and thoſe that are to be obſerved can eaſily be accounted for, by ſuppoſing that ſide to be entirely deſtitute of electric matter. The moſt ſenſible effect of a body charged with electricity is, that when you preſent your finger to it, a ſpark will iſſue from it to your finger: Now when a phial, prepared for the *Leyden* experiment, is hung to the gun-barrel or prime-

con-

conductor, and you turn the globe in order to charge it; as ſoon as the electric matter is excited, you can obſerve a ſpark to iſſue from the external ſurface of the phial to your finger; which, Mr *Franklin* ſays, is the natural electric matter of the glaſs driven out by that received by the inner ſurface from the conductor. If it be only drawn out by ſparks, a vaſt number of them may be drawn; but if you take hold of the external ſurface with your hand, the phial will ſoon receive all the electric matter it is capable of, and the outſide will then be entirely deſtitute of its electric matter, and no ſpark can be drawn from it by the finger: here then is a want of that effect which all bodies, charged with electricity, have. Some of the effects of an electric body, which I ſuppoſe the Abbé has obſerved in the exterior ſurface of a charged phial, are that all light bodies are attracted by it. This is an effect which I have conſtantly obſerved, but do not think that it proceeds from an attractive quality in the exterior ſurface of the phial, but in thoſe light bodies themſelves, which ſeem to be attracted by the phial. It is a conſtant obſervation, that when one body has a greater charge of electric matter in it than another (that is in proportion to the quantity they will hold) this body will attract that which has leſs: Now, I ſuppoſe, and it is a part of Mr *Franklin*'s ſyſtem, that all thoſe light bodies which appear to be attracted, have more electric matter in them than the external ſurface of the phial has, wherefore they endeavour to attract the phial

phial to them, which is too heavy to be moved by the ſmall degree of force they exert, and yet being greater than their own weight, moves them to the phial. The following experiment will help the imagination in conceiving this. Suſpend a cork ball, or a feather by a ſilk thread and electriſe it, then bring this ball nigh to any fixed body, and it will appear to be attracted by that body, for it will fly to it: Now, by the conſent of electricians, the attractive cauſe is in the ball itſelf, and not in the fixed body to which it flies: This is a ſimilar caſe with the apparent attraction of light bodies, to the external ſurface of a charged phial.

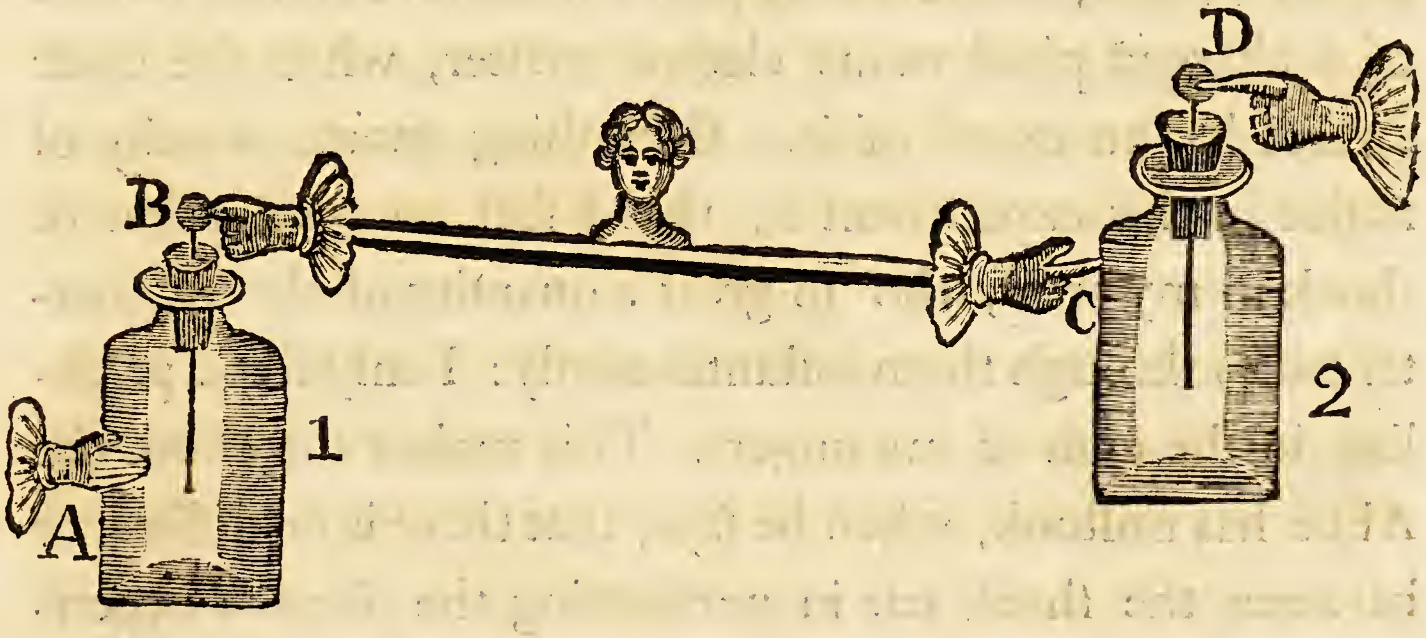
The Abbé ſays, *p.* 69. "that he can electriſe a hundred men, ſtanding on wax, if they hold hands, and if one of them touch one of theſe ſurfaces (the exterior) with the end of his finger": This I know he can, while the phial is charging, but after the phial is charged I am as certain he cannot: That is, hang a phial, prepared for the *Leyden* experiment, to the conductor, and let a man, ſtanding on the floor, touch the coating with his finger, while the globe is turn'd, till the electric matter ſpews out of the hook of the phial, or ſome part of the conductor, which I take to be the certaineſt ſign that the phial has received all the electric matter it can: after this appears, let the man, who before ſtood on the floor, ſtep on a cake of wax, where he may ſtand for hours, and the globe all that time turned, and yet have no appearance of being electriſed. After

ter the electric matter was ſpewed out as above from the hook of a phial, prepared for the *Leyden* experiment, I hung another phial, in like manner prepared, to a hook fixed in the coating of the firſt, and held this other phial in my hand; now if there was any electric matter tranſmitted thro' the glaſs of the firſt phial, the ſecond one would certainly receive and collect it; but having kept the phials in this ſituation for a conſiderable time, during which the globe was continually turned, I could not perceive that the ſecond phial was in the leaſt charged, for when I touched the hook with my finger, as in the *Leyden* experiment, I did not feel the leaſt commotion, nor perceive any ſpark to iſſue from the hook.

I likewiſe made the following experiment. Having charged two phials (prepared for the *Leyden* experiment) through their hooks; two perſons took each one of theſe phials in their hand, one held his phial by the coating, the other by the hook, which he could do by removing the communication from the bottom before he took hold of the hook. Theſe perſons placed themſelves, one on each ſide of me, while I ſtood on a cake of wax, and took hold of the hook of that phial which was held by its coating (upon which a ſpark iſſued, but the phial was not diſcharged, as I ſtood on wax) keeping hold of the hook, I touched the coating of the phial that was held by its hook with my other hand; upon which there was a large ſpark to be ſeen between my finger and the coating, and both phials were

inſtantly

inſtantly diſcharged. If the Abbé's opinion be right, that the exterior ſurface, communicating with the coating, is charged, as well as the interior, communicating with the hook; how can I, who ſtand on wax, diſcharge both theſe phials, when it is well known I could not diſcharge one of them ſingly? Nay, ſuppoſe I have drawn the electric matter from both of them, what becomes of it? For I appear to have no additional quantity in me when the experiment is over, and I have not ſtirr'd off the wax: Wherefore this experiment fully convinces me, that the exterior ſurface is not charged; and not only ſo, but that it wants as much electric matter as the inner has of exceſs: For by this ſuppoſition, which is a part of Mr *Franklin's* ſyſtem, the above experiment is eaſily accounted for, as follows:



When I ſtand on wax, my body is not capable of receiving all the electric matter from the hook of one phial, which it is ready to give; neither can it give as much to the coating of the other phial as it is ready to take, when one is only

applied to me: But when both are applied, the coating takes from one what the hook gives: Thus I receive the fire from the firſt phial at B, the exterior ſurface of which is ſupplied from the hand at A: I give the fire to the ſecond phial at C, whoſe interior ſurface is diſcharged by the hand at D. This diſcharge at D may be made evident by receiving that fire into the hook of a third phial, which is done thus: In place of taking the hook of the ſecond phial in your hand, run the wire of a third phial, prepared as for the *Leyden* experiment, through it, and hold this third phial in your hand, the ſecond one hanging to it, by the ends of the hooks run through each other: When the experiment is performed, this third phial receives the fire at D, and will be charged. When this experiment is conſidered, I think, it muſt fully prove that the exterior ſurface of a charged phial wants electric matter, while the inner ſurface has an exceſs of it. One thing more, worthy of notice in this experiment is, that I feel no commotion or ſhock in my arms, tho' ſo great a quantity of electric matter paſſes through them inſtantaneouſly: I only feel a prickling in the ends of my fingers. This makes me think the Abbé has miſtook, when he ſays, that there is no difference between the ſhock felt in performing the *Leyden* experiment, and the prickling felt on drawing ſimple ſparks, except that of greater to leſs. In the laſt experiment, as much electric matter went through my arms, as would have given me a very ſenſible ſhock, had there been an immediate commu-

munication, by my arms, from the hook to the coating of the ſame phial; becauſe when it was taken into a third phial, and that phial diſcharged ſingly thro' my arms, it gave me a ſenſible ſhock. If theſe experiments prove that the electric matter does not paſs through the intire thickneſs of the glaſs; it is a neceſſary conſequence that it muſt always come out where it enter'd.

The next thing I meet with, is in the Abbé's fifth letter *p.* 88, where he differs from Mr *Franklin*, who thinks that the whole power of giving a ſhock is in the glaſs itſelf, and not in the non-electrics in contact with it. The experiments which Mr *Franklin* gave to prove this opinion in his *Experiments and Obſervations on Electricity*, *Letter* III. *p.* 24. convinced me that he was in the right; and what the Abbé has aſſerted in contradiction thereto, has not made me think otherwiſe. The Abbé perceiving, as I ſuppoſe, that the experiments, as Mr *Franklin* had perform'd them, muſt prove his aſſertion; alters them without giving any reaſon for it, and makes them in a manner that proves nothing. Why will he have the phial, into which the water is to be decanted from a charged phial, held in a man's hand? If the power of giving a ſhock is in the water contain'd in the phial, it ſhould remain there tho' decanted into another phial, ſince no non-electric body touch'd it to take that power off. The phial being placed on wax is no objection, for it cannot take the power from the water, if it had any, but it is a neceſſary

means to try the fact; whereas, that phial's being charged when held in a man's hand, only proves that water will conduct the electric matter. The Abbé owns, *p.* 94. that he had heard this remarked, but ſays, Why is not a conductor of electricity an electric ſubject? This is not the queſtion; Mr *Franklin* never ſaid that water was not an electric ſubject; he ſaid, that the power of giving a ſhock was in the glaſs, and not in the water; and this, his experiments, fully prove; ſo fully, that it may appear impertinent to offer any more: Yet as I do not know that the following has been taken notice of by any body before, my inſerting of it in this place may be excuſed. It is this: Hang a phial, prepared for the *Leyden* experiment, to the conductor, by its hook, and charge it, which done, remove the communication from the bottom of the phial. Now the conductor ſhews evident ſigns of being electriſed; for if a thread be tied round it, and its ends left about two inches long, they will extend themſelves out like a pair of horns; but if you touch the conductor, a ſpark will iſſue from it, and the threads will fall, nor does the conductor ſhew the leaſt ſign of being electriſed after this is done. I think that by this touch, I have taken out all the charge of electric matter that was in the conductor, the hook of the phial, and water or filings of iron contain'd in it; which is no more than we ſee all non-electric bodies will receive; yet the glaſs of the phial retains its power of giving a ſhock, as any one will

find

find that pleafes to try. This experiment fully evidences, that the water in the phial contains no more electric matter than it would do in an open bafon, and has not any of that great quantity which produces the fhock, and is only retain'd by the glafs. If after the fpark is drawn from the conductor, you touch the coating of the phial (which all this while is fuppofed to hang in the air, free from any non-electric body) the threads on the conductor will inftantly ftart up, and fhew that the conductor is electrifed. It receives this electrifation from the inner furface of the phial, which, when the outer furface can receive what it wants from the hand applied to it, will give as much as the bodies in contact with it can receive, or, if they be large enough, all that it has of excefs. It is diverting to fee how the threads will rife and fall by touching the coating and conductor of the phial alternately. May it not be that the difference between the charged fide of the glafs, and the outer or emptied fide, being leffen'd by touching the hook or the conductor; the outer fide can receive from the hand which touched it, and by its receiving the inner fide cannot retain fo much; and for that reafon fo much as it cannot retain electrifes the water, or filings and conductor: For it feems to be a rule, that the one fide muft be emptied in the fame proportion that the other is fill'd: Tho' this from experiment appears evident, yet it is ftill a myftery not to be accounted for.

I am

I am, in many places of the Abbé's book, ſurpriſed to find that experiments have ſucceeded ſo differently at *Paris* from what they did with Mr *Franklin*, and as I have always obſerv'd them to do. The Abbé, in making experiments to find the difference between the two ſurfaces of a charged glaſs, will not have the phial placed on wax: For, ſays he, don't you know that being placed on a body originally electric, it quickly loſes its virtue? I cannot imagine what ſhould have made the Abbé think ſo; it certainly is contradictory to the notions commonly received of electrics per ſe; and by experiment I find it entirely otherwiſe: For having ſeveral times left a charged phial, for that purpoſe, ſtanding on wax for hours, I found it to retain as much of its charge as another that ſtood at the ſame time on a table. I left one ſtanding on wax from 10 o'clock at night till 8 next morning, when I found it to retain a ſufficient quantity of its charge, to give me a ſenſible commotion in my arms, though the room in which the phial ſtood had been ſwept in that time, which muſt have rais'd much duſt to facilitate the diſcharge of the phial.

I find that a cork ball ſuſpended between two bottles, the one fully and the other but little charged, will not play between them, but is driven into a ſituation that makes a triangle with the hooks of the phials; though the Abbé has aſſerted the contrary of this, *p.* 101, in order to account for the playing of a cork ball between the

wire

wire thruſt into the phial, and one that riſes up from its coating. The phial which is leaſt charged muſt have more electric matter given to it, in proportion to its bulk, than the cork ball receives from the hook of the full phial.

The Abbé ſays, *p.* 103, "that a piece of metal leaf "hung to a ſilk thread and electriſed, will be repell'd by "the bottom of a charged phial held by its hook in the "air;" This I find conſtantly otherwiſe, it is with me always firſt attracted and then repelled: It is neceſſary in charging the leaf to be careful that it does not fly off to ſome non-electric body, and ſo diſcharge itſelf when you think it is charged; it is difficult to keep it from flying to your own wriſt, or to ſome part of your body.

The Abbé, *p.* 108, ſays, "that it is not impoſſible, as "Mr *Franklin* ſays it is, to charge a phial while there is a "communication form'd between its coating and its hook". I have always found it impoſſible to charge ſuch a phial ſo as to give a ſhock: Indeed if it hang on the conductor without a communication from it, you may draw a ſpark from it as you may from any body that hangs there, but this is very different from being charged in ſuch a manner as to give a ſhock. The Abbé, in order to account for the little quantity of electric matter that is to be found in the phial, ſays, "that it rather follows the metal than the "glaſs, and that it is ſpewed out into the air from the coating "of the phial". I wonder how it comes not to do ſo too,

when

when it ſifts through the glaſs and charges the exterior ſurface, according to the Abbé's ſyſtem!

The Abbé's objections againſt Mr *Franklin*'s two laſt experiments, I think, have little weight in them: He ſeems, indeed, much at a loſs what to ſay, wherefore he taxes Mr *Franklin* with having conceal'd a material part of the experiment; a thing too mean for any gentleman to be charged with, who has not ſhewn as great a partiality in relating experiments, as the Abbé has done.

ELEC-

ELECTRICAL EXPERIMENTS,

With an Attempt to account for their

SEVERAL PHÆNOMENA;

Together with

Some Obſervations on *Thunder-Clouds*,

In further Confirmation of Mr FRANKLIN's Obſervations on the poſitive and negative electrical State of the Clouds, by JOHN CANTON, M. A. and F. R. S.

Dec. 6, 1753.

EXPERIMENT I.

FROM the cieling, or any convenient part of a room, let two cork-balls, each about the bigneſs of a ſmall pea, be ſuſpended by linen threads of eight or nine inches in length, ſo as to be in contact with each other. Bring the excited glaſs tube under the balls,

and they will be ſeparated by it, when held at the diſtance of three or four feet; let it be brought nearer, and they will ſtand farther apart; intirely withdraw it, and they will immediately come together. This experiment may be made with very ſmall braſs balls hung by ſilver wire; and will ſucceed as well with ſealing-wax made electrical, as with glaſs.

EXPERIMENT II.

If two cork-balls be ſuſpended by dry ſilk threads, the excited tube muſt be brought within eighteen inches before they will repel each other; which they will continue to do, for ſome time, after the tube is taken away.

As the balls in the firſt experiment are not inſulated, they cannot properly be ſaid to be electrified: but when they hang within the atmoſphere of the excited tube, they may attract and condenſe the electrical fluid round about them, and be ſeparated by the repulſion of its particles. It is conjectur'd alſo, that the balls at this time contain leſs than their common ſhare of the electrical fluid, on account of the repelling power of that which ſurrounds them; tho' ſome, perhaps, is continually entering and paſſing thro' the threads. And if that be the caſe, the reaſon is plain, why the balls hung by ſilk, in the ſecond experiment, muſt be in a much more denſe part of the atmoſphere of the tube, before they will repel each other. At the approach of an excited ſtick of wax to the balls, in the firſt experiment, the electrical fire is ſuppoſed to

come

come through the threads into the balls, and be condenſed there, in its paſſage towards the wax: for, according to Mr *Franklin*, excited glaſs *emits* the electrical fluid, but excited wax *receives* it.

EXPERIMENT III.

Let a tin tube, of four or five feet in length, and about two inches inches in diameter, be inſulated by ſilk; and from one end of it let the cork-balls be ſuſpended by linen threads. Electrify it, by bringing the excited glaſs tube near the other end, ſo as that the balls may ſtand an inch and an half, or two inches apart: then, at the approach of the excited tube, they will by degrees loſe their repelling power, and come into contact; and as the tube is brought ſtill nearer, they will ſeparate again to as great a diſtance as before: in the return of the tube they will approach each other till they touch, and then repel as at firſt. If the tin-tube be electrified by wax, or the wire of a charg'd phial, the balls will be affected in the ſame manner at the approach of excited wax, or the wire of the phial.

EXPERIMENT IV.

Electrify the cork-balls as in the laſt experiment by glaſs; and at the approach of an excited ſtick of wax their repulſion will be increaſed. The effect will be the ſame, if the excited glaſs be brought towards them, when they have been electrified by wax.

The bringing the excited glaſs to the end, or edge of

the tin-tube, in the third experiment, is ſuppos'd to electrify it poſitively, or to add to the electrical fire it before contained; and therefore ſome will be running off through the balls, and they will repel each other. But at the approach of excited glaſs, which likewiſe *emits* the electrical fluid, the diſcharge of it from the balls will be diminiſh'd; or part will be driven back, by a force acting in a contrary direction; and they will come nearer together. If the tube be held at ſuch a diſtance from the balls, that the exceſs of the denſity of the fluid round about them, above the common quantity in air, be equal to the exceſs of the denſity of that within them, above the common quantity contain'd in cork; their repulſion will be quite deſtroy'd. But if the tube be brought nearer; the fluid without, being more denſe than that within the balls, it will be attracted by them, and they will recede from each other again.

When the apparatus has loſt part of its natural ſhare of this fluid, by the approach of excited wax to one end of it, or is electrified negatively; the electrical fire is attracted and imbib'd by the balls to ſupply the deficiency; and that more plentifully at the approach of excited glaſs, or a body poſitively electrified, than before; whence the diſtance between the balls will be increaſed, as the fluid ſurrounding them is augmented. And in general, whether by the approach or receſs of any body; if the difference between the denſity of the internal and external fluid be

be increaſed, or diminiſhed; the repulſion of the balls will be increaſed, or diminiſhed, accordingly.

EXPERIMENT V.

When the inſulated tin tube is not electrified, bring the excited glaſs tube towards the middle of it, ſo as to be nearly at right angles with it, and the balls at the end will repel each other; and the more ſo, as the excited tube is brought nearer. When it has been held a few ſeconds, at the diſtance of about ſix inches, withdraw it, and the balls will approach each other till they touch; and then ſeparating again, as the tube is moved farther off, will continue to repel when it is taken quite away. And this repulſion between the balls will be increaſed by the approach of excited glaſs, but diminiſhed by excited wax; juſt as if the apparatus had been electrified by wax, after the manner deſcribed in the third experiment.

EXPERIMENT VI.

Inſulate two tin tubes, diſtinguiſhed by *A* and *B*, ſo as to be in a line with each other, and about half an inch apart; and at the remote end of each, let a pair of cork balls be ſuſpended. Towards the middle of *A*, bring the excited glaſs tube; and holding it a ſhort time, at the diſtance of a few inches, each pair of balls will be obſerved to ſeparate: withdraw the tube, and the balls of *A* will come together, and then repel each other again; but thoſe of *B* will hardly be affected. By the approach of the ex-

cited

cited glaſs tube, held under the balls of *A*, their repulſion will be increaſed: but if the tube be brought, in the ſame manner, towards the balls of *B*, their repulſion will be diminiſhed.

In the fifth experiment, the common ſtock of electrical matter in the tin tube, is ſuppoſed to be attenuated about the middle, and to be condenſed at the ends, by the repelling power of the atmoſphere of the excited glaſs tube, when held near it. And perhaps the tin tube may loſe ſome of its natural quantity of the electrical fluid, before it receives any from the glaſs; as that fluid will more readily run off from the ends or edges of it, than enter at the middle: and accordingly, when the glaſs tube is withdrawn, and the fluid is again equally diffuſed through the apparatus, it is found to be electrified negatively: For excited glaſs brought under the balls will increaſe their repulſion.

In the ſixth experiment, part of the fluid driven out of one tin tube enters the other; which is found to be electrified poſitively, by the decreaſing of the repulſion of its balls, at the approach of excited glaſs.

EXPERIMENT VII.

Let the tin tube, with a pair of balls at one end, be placed three feet at leaſt from any part of the room, and the air render'd very dry by means of a fire: electrify the apparatus to a conſiderable degree; then touch the tin tube with a finger, or any other conductor, and the balls

will,

will, notwithſtanding, continue to repel each other; tho' not at ſo great a diſtance as before.

The air ſurrounding the apparatus to the diſtance of two or three feet, is ſuppoſed to contain more or leſs of the electrical fire, than its common ſhare, as the tin tube is electrified poſitively, or negatively; and when very dry, may not part with its overplus, or have its deficiency ſupplied ſo ſuddenly, as the tin; but may continue to be electrified, after that has been touch'd for a conſiderable time.

EXPERIMENT VIII.

Having made the Torricellian vacuum about five feet long, after the manner deſcribed in the *Philoſophical Tranſactions*, Vol. xlvii. p. 370. if the excited tube be brought within a ſmall diſtance of it, a light will be ſeen through more than half its length: which ſoon vaniſhes, if the tube be not brought nearer; but will appear again, as that is moved farther off. This may be repeated ſeveral times, without exciting the tube afreſh.

This experiment may be conſider'd as a kind of ocular demonſtration of the truth of Mr *Franklin*'s hypotheſis; that when the electrical fluid is condenſed on one ſide of thin glaſs, it will be repelled from the other, if it meets with no reſiſtance. According to which, at the approach of the excited tube, the fire is ſuppoſed to be repelled from the inſide of the glaſs ſurrounding the vacuum, and to be carried

carried off through the columns of mercury; but, as the tube is withdrawn, the fire is ſuppoſed to return.

EXPERIMENT IX.

Let an excited ſtick of wax, of two feet and an half in length, and about an inch in diameter, be held near its middle. Excite the glaſs tube, and draw it over one half of it; then, turning it a little about its axis, let the tube be excited again, and drawn over the ſame half; and let this operation be repeated ſeveral times: then will that half deſtroy the repelling power of balls electrified by glaſs, and the other half will increaſe it.

By this experiment it appears, that wax alſo may be electrified poſitively and negatively. And it is probable, that all bodies whatſoever may have the quantity they contain of the electrical fluid, increaſed, or diminiſhed. The clouds, I have obſerved, by a great number of experiments, to be ſome in a poſitive, and others in a negative ſtate of electricity. For the cork balls, electrified by them, will ſometimes cloſe at the approach of excited glaſs; and at other times be ſeparated to a greater diſtance. And this change I have known to happen five or ſix times in leſs than half an hour; the balls coming together each time, and remaining in contact a few ſeconds, before they repel each other again. It may likewiſe eaſily be diſcover'd, by a charged phial, whether the electrical fire be drawn out of the apparatus by a negative cloud, or forced into it by a poſi-

a poſitive one: and by whichſoever it be electrified, ſhould that cloud either part with its overplus, or have its deficiency ſupplied ſuddenly, the apparatus will loſe its electricity: which is frequently obſerved to be the caſe, immediately after a flaſh of lightning. Yet when the air is very dry, the apparatus will continue to be electriſed for ten minutes, or a quarter of an hour, after the clouds have paſſed the zenith; and ſometimes till they appear more than half-way towards the horizon. Rain, eſpecially when the drops are large, generally brings down the electrical fire: and hail, in ſummer, I believe never fails. When the apparatus was laſt electrified, it was by the fall of thawing ſnow; which happened ſo lately, as on the 12th of *November*; that being the twenty-ſixth day, and ſixty-firſt time, it has been electrified, ſince it was firſt ſet up; which was about the middle of *May*. And as *Fahrenheit*'s thermometer was but ſeven degrees above freezing, it is ſuppoſed the winter will not intirely put a ſtop to obſervations of this ſort. At *London*, no more than two thunderſtorms have happened during the whole ſummer: and the apparatus was ſometimes ſo ſtrongly electrified in one of them, that the bells, which have been frequently rung by the clouds, ſo loud as to be heard in every room of the houſe (the doors being open), were ſilenced by the almoſt conſtant ſtream of denſe electrical fire, between each bell and the braſs ball, which would not ſuffer it to ſtrike.

I ſhall conclude this paper, already too long, with the following queries:

1. May not air, ſuddenly rarefied, give electrical fire to, and air ſuddenly condenſed, receive electrical fire from, clouds and vapours paſſing through it?

2. Is not the *aurora borealis*, the flaſhing of electrical fire from poſitive, towards negative clouds at a great diſtance, through the upper part of the atmoſphere, where the reſiſtance is leaſt?

APPENDIX.

AS Mr *Franklin*, in a former letter to Mr *Collinſon*, mentioned his intending to try the power of a very ſtrong electrical ſhock upon a turkey, that gentleman accordingly has been ſo very obliging as to ſend an account of it, which is to the following purpoſe.

He made firſt ſeveral experiments on fowls, and found, that two large thin glaſs jars gilt, holding each about ſix gallons, and ſuch as I mentioned I had employed in the laſt paper I laid before you on this ſubject, were ſufficient, when fully charged, to kill common hens outright; but the turkeys, though thrown into violent convulſions, and then, lying as dead for ſome minutes, would recover in leſs than a quarter of an hour. However, having added three other ſuch to the former two, though not fully charged, he killed a turkey of about ten pounds weight, and believes that they would have killed a much larger. He conceited, as himſelf ſays, that the birds kill'd in this manner eat uncommonly tender.

In making theſe experiments, he found, that a man could, without great detriment, bear a much greater ſhock than he imagined: for he inadvertently received the ſtroke of two of theſe jars through his arms and body, when they were very near fully charged. It ſeemed to him an univerſal blow throughout the body from head to foot,

and

and was followed by a violent quick trembling in the trunk, which went off gradually in a few ſeconds. It was ſome minutes before he could recollect his thoughts, ſo as to know what was the matter; for he did not ſee the flaſh, tho' his eye was on the ſpot of the prime conductor, from whence it ſtruck the back of his hand; nor did he hear the crack, though the by-ſtanders ſaid it was a loud one; nor did he particularly feel the ſtroke on his hand, tho' he afterwards found it had raiſed a ſwelling there, of the bigneſs of half a ſwan-ſhot, or piſtol-bullet. His arms and the back of his neck felt ſomewhat numbed the remainder of the evening, and his breaſt was ſore for a week after, as if it had been bruiſed. From this experiment may be ſeen the danger, even under the greateſt caution, to the operator, when making theſe experiments with large jars; for it is not to be doubted, but ſeveral of theſe fully charged would as certainly, by increaſing them, in proportion to the ſize, kill a man, as they before did a turkey.

N. B. The original of this letter, which was read at the Royal Society, has been miſlaid.

FINIS.

1682 ——— NEW EXPERIMENTS and OBSERVATIONS on ELECTRICITY, made at Philadelphia in America, and communicated in several Letters to PETER COLLINSON, of London, F.R.S. [Parts I—III; Part I edited, with Preface, by PETER COLLINSON, F.R.S.]; THIRD EDITION of PARTS I and II, and **first edition** of PART III, *with copperplate*, 3 parts in one vol. 4to. *hf. parchment* (*plate defective*), £1. 1*s* *D. Henry and R. Cave, at St. John's Gate*, 1760-2-54

The first part consists of four letters, the last on 'Observations and Suppositions towards forming a new Hypothesis, for explaining the Phenomena of Thunder Gusts', with Additional Papers by Peter Collinson.

The second and third part contain thirteen additional letters, also 'Remarks on the Abbé Nollet's Letters on Electricity to Benjamin Franklin by DAVID COLDEN, of New-York,' and 'Electrical Experiments, with an Attempt to account for their several Phænomena: with some Observations on Thunder-Clouds, by JOHN CANTON, F.R.S.', the last passage reading: 'Is not the *aurora borealis* the flashing of electrical fire from positive towards negative clouds at a great distance, through the upper part of the atmosphere, where the resistance is least?'

The work started a new era in electrical science and contains a number of valuable experiments and suggestions, *e.g.*, his 'one-fluid theory' of electricity and the 'Franklin Plate,' explaining the theory of the Leyden Jar, the discovery of the electric action of points, which resulted in his invention of the lightning-conductor, etc. etc. etc.

'They were not originally designed for publication, but Collinson thought them too important to be withheld. The public interest in these experiments justified Collinson's anticipations. 'Nothing,' says Priestley, 'ever written on the subject was more justly applauded. All the world, even kings, flocked to see them, and retired full of admiration'.'